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Maritime Prepositioning Force (MPF)
Throughput Analysis of a
Marine Expeditionary Unit (MEU) Slice Offload

by

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This thesis describes the design and employment of a general transportation and distribution simulation toolbox and an extension to that toolbox used to model the instream offload of a Marine Expeditionary Unit (MEU) Slice of a Maritime Prepositioning Force (MPF). The Simulated Mobility Modeling and Analysis Toolbox (SMMAT) is a toolbox of object oriented modules written in MODSIM II® by faculty and students, including the author, of the Naval Postgraduate School for transportation and distribution modeling. The MEU Slice offload model is built as an extension to SMMAT, with itself being easily extendible to model other aspects of MPF operations. The objective of this thesis was twofold, (1) to build SMMAT and demonstrate its feasibility as a toolbox, and (2) to determine which of four asset distribution setups ashore, at varying levels of equipment reliability, will allow for the fastest offload and throughput of the MEU slice. This thesis successfully demonstrated SMMAT's usefulness as a transportation and distribution simulation toolbox, and the MEU Slice study indicates that no one distribution setup ashore is statistically faster than any other one.

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Maritime Prepositioning Force (MPF) Throughput Analysis of A Marine Expeditionary Unit (MEU) Slice Offload

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ABSTRACT

This thesis describes the design and employment of a general transportation and distribution simulation toolbox and an extension to that toolbox used to model the instream offload of a Marine Expeditionary Unit (MEU) Slice of a Maritime Prepositioning Force (MPF). The Simulated Mobility Modeling and Analysis Toolbox (SMMAT) is a toolbox of object oriented modules written in MODSIM II® by faculty and students, including the author, of the Naval Postgraduate School for transportation and distribution modeling. The MEU Slice offload model is built as an extension to SMMAT, with itself being easily extendible to model other aspects of MPF operations. The objective of this thesis was twofold, (1) to build SMMAT and demonstrate its feasibility as a toolbox, and (2) to determine which of four asset distribution setups ashore, at varying levels of equipment reliability, will allow for the fastest offload and throughput of the MEU slice. This thesis successfully demonstrated SMMAT's usefulness as a transportation and distribution simulation toolbox, and the MEU Slice study indicates that no one distribution setup ashore is statistically faster than any other one.

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EXECUTIVE SUMMARY

A. BACKGROUND

Following the Iranian hostage crisis of 1979, the Department of Defense began exploring the concept of using prepositioned equipment to aid in contingency rapid response. The Marine Corps' long term answer to this initiative was the formation of today's Maritime Prepositioning Force (MPF). The MPF is the marriage of a Maritime Prepositioning Ship (MPS) Squadron (MPSRON) and a Marine Expeditionary Brigade (MEB). Three MPSRON's are afloat independently throughout the world awaiting the call to join with a Marine Air Ground Task Force (MAGTF) for rapid deployment in case of crisis prevention and intervention.

When the MPS's were first loaded (1984 - 1986), all ships were evenly loaded with equipment and supplies to reduce the impact of one or more ships being lost or unable to participate in an operation. This spreadloading forced the use of the entire MPSRON or none of it. The MPSRON could not effectively offload just the equipment and supplies needed to support a smaller MAGTF. In the mid to late 1980's, the following force modules were developed, and later implemented, for a more flexible employment of the MPF.

- <u>the MEU Slice</u> - all equipment comes from one MPS ship, capable of providing 2,700 Marines with 15 days of sustainment.

- <u>the Low Intensity Conflict MEB [LIC MEB (1)]</u> - all equipment comes from two MPS ships and an afloat MEU of four or five amphibious ships. It is capable of providing 12,500 Marines with 30 days of sustainment.

- <u>the LIC MEB (2)</u> - from three or four MPS ships (depending on which MPSRON is involved). It is capable of providing 12,500 Marines with 30 days of sustainment.

- <u>the full MEB</u> - the entire MPSRON. It is capable of providing 16,500 Marines with 30 days of sustainment.

B. MPF OPERATIONS

The MPF may be employed in many types of situations, from a humanitarian assistance effort utilizing a MEU Slice to the employment of an entire MEF with all three MPSRON's. Every MPF employment can be broken into four distinct phases: the planning phase, the marshaling phase, the movement phase, and the arrival and assembly phase. The first three phases can occur simultaneously or partially overlap in time; they constitute the most administrative aspects of the operation. Phase IV, the arrival and assembly phase, is the most crucial phase of an MPF operation. During the arrival and assembly, the equipment and supplies flow from the ships to the port and beach, and then from the port and beach to the Marine units inland. The arrival and assembly phase is the area of interest for this thesis.

C. METHODOLOGY

An MPF offload is not a serial process and cannot be easily modeled analytically. Many events occur simultaneously, such as crane operations aboard ship and Logistics Vehicle System (LVS) / Rough Terrain Container Handler (RTCH) operations ashore. Simulation was chosen as the modeling method, using the object oriented simulation language MODSIM II®, in that it easily allows parallel events to occur. Previous simulation models have looked at similar aspects of ship offloading, but for container-only and vehicle-only offloads. Because the MEU Slice offload takes much less time than a multiple ship offload, it is very sensitive to errors in assumptions. Therefore, this model has greater fidelity so that assumptions as to when the LVS's and RTCH's get ashore are unnecessary. Each specific piece of equipment is modeled, not just generic vehicles and containers. When an LVS or RTCH gets ashore in this model, it becomes available to move and load containers.

This simulation was written using the Simulated Mobility Modeling and Analysis Toolbox (SMMAT), of which the author was a co-developer. The need for this product was conceived by Professor Mike Bailey and Professor Bill Kemple of the Naval

Postgraduate School in January 1994, to allow students to conduct thesis research on logistics problems on a larger scale than previously possible. SMMAT is a collection of objects and processes designed to facilitate the modeling of materiel movement along a network. The primary components of SMMAT are junctions, transporters, loaders, and cargo. Within SMMAT, cargo is moved between junctions by transporters, and is transferred between junction and transporters with loaders. Delivery can be determined by the route of the transporters, or can be determined strictly on the basis of cargo destination, with SMMAT choosing the transporter based on availability and compatibility with cargo, junction, and loader. Once SMMAT was operational, it was used as the basis for the author's MEU Slice model.

D. DATA ANALYSIS / CONCLUSION

SMMAT proved to be extremely useful as the toolbox on which the author's MEU Slice Model was built. Once completed, it provided the author with a steady base on which to then produce a more specific model. This thesis demonstrated SMMAT's usefulness as a toolbox; with this powerful modeling toolbox now available, future students will now be able to study more difficult problems in much more detail.

The experiment for this thesis, which tested time to completion of the MEU Slice offload, was conducted as a 2 x 4 full factorial design, with the simulation model being used to generate data for each of the configurations that resulted from four setup options and two reliability levels. Each run produced 30 replications. The data collected was first analyzed with a two-factor Analysis of Variance (ANOVA), followed by graphical analysis and pairwise differences.

From the eight experiments run, it was determined that there was no significant differences between the setup options or reliability levels, or any significant interaction between the two. Future study is recommended as this is not what the author was anticipating. Additional analysis should include increasing fidelity between the RTCH's and LVS's, with a comparison against the original results to test for a significant difference.

I. INTRODUCTION

A. MARITIME PREPOSITIONING FORCE (MPF) BACKGROUND

Following the Iranian hostage crisis of 1979, the Department of Defense began exploring the concept of using prepositioned equipment to aid in contingency rapid response. The Marine Corps' answer to this initiative was the formation of the Near-Term Prepositioning Force (NTPF), the precursor of today's MPF. The NTPF, deployed in the Indian Ocean, was made up of seven ships containing equipment for the 7th Marine Expeditionary Brigade (MEB).[1] The NTPF was designed to be a short term solution until the MPF was operational. This could not occur until the thirteen ships of the three Maritime Prepositioning Ship (MPS) Squadrons (MPSRON's) were completed. (CRM 89-339, pp. 3, 4).

These three MPSRON's are afloat independently throughout the world (in the Atlantic Ocean, the Pacific Ocean, and in the Indian Ocean) awaiting the call to marry up with a Marine Air Ground Task Force (MAGTF). This marriage of an MPSRON with the personnel of a MAGTF produces an MPF. The MPF concept follows that of the NTPF, to allow for the rapid deployment of a MEB for crisis prevention and intervention. The MPF's provide the United States with "... a balanced, sustainable, multi-role, middleweight, combined arms crisis response team." (Dalton, Kelso, and Mundy, April 1994, p. 20)

When the MPS's were first loaded (1984 - 1986), all ships were evenly loaded with Maritime Prepositioned equipment and supplies (MPE/S) to reduce the impact of one or more ships being lost or unable to participate in an operation. This spreadloading forced

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1 A MEB is a specific type of Marine Air-Ground Task Force (MAGTF). A MAGTF is formed when headquarters, aviation, ground combat, and ground combat service support personnel are brought together under one command for a specific mission or objective. The three most common MAGTG's are, from largest to smallest, the Marine Expeditionary Force (MEF), the MEB, and the Marine Expeditionary Unit (MEU).

the use of the entire MPSRON or none of it. The MPSRON could not effectively offload just the MPE/S needed to support a smaller MAGTF. In the mid to late 1980's, dissussions throughout Headquarters, Marine Corps (HQMC) centered around the possibility of restructuring the MPSRON's. Though the MPF had been extremely successful in past operations, it needed to be made more responsive and flexible for future contingencies (A.M. Gray, Speech, 1 Sept 1989). Due to these discussions, the Commanding Generals, Atlantic and Pacific Fleet Marine Forces (CGFMFLant and CGFMFPac) were tasked to study and develop a suite of varying MPF force modules for use by the Unified Commanders in case of contingencies and crises. Following this initial study, the Center for Naval Analysis (CNA) was asked to refine this concept of force modules. From CNA's study, the present Force Module Concept was born. This concept allows for more flexible MPF employment; each MPSRON can be unloaded in different ways to let it meet any one of the following four distinct threat levels:

- the MEU Slice - all equipment comes from one MPS ship, capable of providing 2,700 Marines with 15 days of sustainment.
- the Low Intensity Conflict MEB [LIC MEB (1)] - all equipment comes from two MPS ships and an afloat MEU of four or five amphibious ships. It is capable of providing 12,500 Marines with 30 days of sustainment.
- the LIC MEB (2) - from three or four MPS ships (depending on which MPSRON is involved). It is capable of providing 12,500 Marines with 30 days of sustainment.
- the full MEB - the entire MPSRON. It is capable of providing 16,500 Marines with 30 days of sustainment. (CNA CNR 190, March 1991, p. 3)

Desert Shield and Desert Storm provided the Marine Corps with the opportunity to reconfigure the MPSRON's with the force modules sooner than expected. When the MPSRON's were regenerated after Desert Storm, the ships could be loaded under with the new force modules in place.[2]

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2 Regeneration is the methodical approach to restore the MPSRON to its original strength and to attain full operational capability. In this case, it involved restructuring the types and quantities of MPE/S aboard the individual ships.

B. PROBLEM

During the Cold War, all MPF operational and logistical planning was completed assuming full employment of the force. In the Post Cold War era, using the force modules, it is no longer guaranteed that an MPF will be deployed in full. The MPF has "a capability of individual ship, squadron, or force employment to deliver on-scene humanitarian assistance or a fully combat-ready Marine Expeditionary Force." (Dalton, Kelso, and Mundy, April 1994, p. 20) A very likely scenario is the deployment of the MEU Slice, the smallest of the four levels, in a humanitarian assistance effort. This would be similar to OPERATION RESTORE HOPE, the humanitarian relief of Somalia, but on a smaller scale. Present MPF doctrine calls for the rapid deployment of a MAGTF and MPSRON to a secure environment where the offload and marrying up can occur (FMFM 1-5, p. 1-1). In the humanitarian assistance scenario, the offload environment may not be quite as secure as hoped. The total offload and throughput time becomes critical since the Marines supporting the operation are extremely vulnerable until their marriage with the MPE/S is complete.

In the worst case, the MEU Slice would have to be offloaded with MEU Slice equipment only. This would occur if no port facility was available; the offload would then proceed instream vice pierside.[3] But, the MEU Slice includes only limited material handling equipment (three Rough Terrain Container Handlers [RTCH's]) and transportation assets (seven Logistic Vehicle Systems [LVS's]), so the allocation of these resources is believed critical to minimizing the throughput time. Also, since the force modules are relatively untried, the best setup of the Arival and Assembly Area (AAA) for a MEU Slice offload supporting a humanitarian assistance effort is not known.[4] This thesis

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[3] An instream offload occurs when the ship anchors offshore and lighterages transport the equipment and supplies ashore.

[4] The best setup is the one that allows for the quickest marriage of Marines and equipment.

will look at four possible setups of the AAA and determine which provides for the quickest offload and throughput.

The setup of the AAA is determined by the RTCH allocation. Each Container Operations Terminal (COT), designed to receive all containers for the associated Major Subordinate Element (MSE), will require at least one RTCH.[5] The following describes the four candidate organizational options within the AAA for the setup of the COT's.

- One COT, using two RTCH's at the beach and one RTCH at the COT.
- One COT, using one RTCH at the beach and two RTCH's at the COT.
- Two COT's, using one RTCH at the beach and one RTCH at each COT. The first COT will receive containers for the CE and the GCE; the second COT, for the CSSE and the ACE.
- Two COT's, using one RTCH at the beach and one RTCH at each COT. The first COT will receive containers for the CE, the GCE, and the CSSE; the second COT, for the ACE.

The setup which gives the quickest offload and throughput is not necessarily the setup that the MAGTF Commander should choose. The quickest setup may not be the most tactically sound. This model will provide him with one extra piece of information with which this decision can be made.

[5] The MSE's are the Command Element (CE), the Ground Combat Element (GCE), the Combat Service Support Element (CSSE), and the Aviation Combat Element (ACE).

II. MPF OPERATIONS

A. MPF OVERVIEW

The MPF may be employed in many types of situations, from a humanitarian assistance effort utilizing a MEU Slice to the employment of an entire MEF with all three MPSRON's. Every MPF employment can be broken into four distinct phases: the planning phase, the marshalling phase, the movement phase, and the arrival and assembly phase (OH 1-5-1, pp. 1-5, 1-6). The first three phases can occur simultaneously or partially overlap in time. In addition, they constitute the most administrative aspects of the operation. Phase IV, the arrival and assembly phase, is the "final and most crucial phase of an MPF operation." (FMFM 1-5, p. 8-1) The first three phases are controlled by both the MAGTF Commander and the Commander, MPF (CMPF). The MAGTF Commander controls the ground and air side of planning, marshaling, and movement while the CMPF controls the sea aspects. They must also coordinate so that all issues are covered. The arrival and assembly phase is where most of the interaction takes place. The CMPF controls the flow of equipment and supplies from the ships to the port and beach, while the MAGTF Commander controls the flow from the port and beach through the AAA. The arrival and assembly phase is the area of interest for this thesis. Before the specifics of the arrival and assembly are discussed, a general understanding of the entire MPF operation is necessary.

1. The Phases of Operation

a. Planning Phase

The planning phase starts with the issuance of a warning order and continues throughout the entire operation (FMFM 1-5, p. 2-8). This phase encompasses both contingency and execution planning. Contingency planning takes place when only a hypothetical situation is known while execution planning occurs when the commitment of

a force is imminent. (FMFM 1-5, pp. 3-1, 3-2). The concepts for marshaling, movement, and arrival and assembly are developed during this phase. The MAGTF Commander and the CMPF must work together in this phase.

b. Marshaling Phase

The marshaling phase begins with the first Marines and Sailors arrive at a marshaling area and is complete when the final aircraft leaves the departure airfield. (FMFM 1-5, p. 2-10) The movement of Marines and equipment from their home base to the marshaling area falls within this phase. This is controlled by the MAGTF Commander.

c. Movement Phase

The movement phase begins when the first Marines or ships begin transiting toward the Area of Operations and ends with the last Marine or ship entering the AAA (FMFM 1-5, p. 2-12). During this phase, the Force is separated into elements that will deploy by air, the Fly in Echelon (FIE), and the elements that will deploy by sea, the MPSRON and associated support ships. The MAGTF Commander controls the FIE while the CMPF controls the movement by sea. A detailed breakdown of the FIE will appear later.

d. Arrival and Assembly Phase

The arrival and assembly phase begins with the arrival of the first Marine of the Main Body or ship of the MPSRON at the AAA and is complete when the MAGTF is combat capable. The CMPF decides when termination of the MPF operation is necessary, based on the recommendation of the MAGTF Commander. It is not necessarily when the final supply or piece of equipment is married with its designated unit. This phase includes the reception of all Marines and equipment and the distribution of equipment and supplies to the Marines (FMFM 1-5, p. 2-14). The MAGTF Commander controls operations ashore while the CMPF controls operations at sea. The MAGTF forms separate arrival and assembly organizations to execute the timely and thorough throughput of equipment and supplies.

2. The Fly-In-Echelon (FIE)

a. Survey, Liaison, and Reconnaissance Party (SLRP)

The purpose of the SLRP is to assess conditions, conduct initial reconnaissance, and make liaison with local authorities, if appropriate, and to report the findings to MAGTF Commander. Ideally it will deploy five to seven days prior to the MPSRON. (MPF Staff Planning Course [SPC], p. HO-315-1-2)

b. Offload Preparation Party (OPP)

The OPP is a temporary element comprised of maintenance personnel, embarkation personnel, and equipment operators; its purpose is to help the ships' crews prepare offload systems and equipment for debarkation once they arrive in port. The OPP ideally will meet the MPSRON no later than four days before it arrives at the AAA. The OPP will dis-establish on arrival at the AAA, and its members will become the skeleton of the debark crew. (MPF SPC, pp. HO-314-1-2 - HO-314-1-4)

c. Advance Party

The Advance Party is the next element of the FIE to arrive at the AAA; it is made up of representatives from all MSE's. They link up with the SLRP to organize offload control agencies and to ready the AAA for the Main Body arrival. They also augment the OPP to form the remainder of the debarkation crew.

d. Main Body

The Main Body is comprised of the rest of the FIE Marines not mentioned in one of the previous elements. It also includes equipment necessary for the operation. For a full MEB offload, it should not exceed 250 sorties aboard Air Force transports. The Main Body arrival at the AAA must be coordinated in such a way as to mirror the offload of the ships.

e. Flight Ferry

The Flight Ferry involves the aircraft from the ACE that can self-deploy to the AAA with support of aerial refueling (FMFM 1-5, p. 7-4).

3. Arrival and Assembly Organizations

a. Arrival and Assembly Operations Group (AAOG)

The AAOG, whose nucleus is from the SLRP, is comprised of personnel from all MSE's of the MAGTF, and it is responsible for coordination of the arrival and assembly operations. This includes both the flow of personnel and equipment from the arrival airfield to the AAA and the flow of equipment and supplies from the port and beach to the MSE's. They work closely with the NSE's Primary Control Officer (PCO), who controls the flow of equipment and supplies from the MPSRON to the port and beach.

b. Landing Force Support Party (LFSP)

The LFSP is an element of the CSSE and is responsible to the AAOG for the throughput of personnel, equipment, and supplies at the arrival airfield, beach, and port. The LFSP is made up of the following elements.

(1) Beach Operations Group (BOG). During an instream offload, the BOG must work closely with the NSE's Beach Party Group, who controls the landing of lighterages at the beach.

(2) Port Operations Group (POG). During a pierside offload, the POG must work directly with the ship's debarkation officer to ensure the timely offload of each ship.

(3) Arrival Airfield Control Group (AACG). The AACG must coordinate with the Air Force to ensure the timely arrival of personnel and equipment.

c. *Arrival and Assembly Operations Elements (AAOE's)*

An AAOE is formed for each MSE, and its purpose is to receive equipment and supplies from the LFSP, depreserve and perform maintenance when necessary, and pass on usable equipment and supplies to the using units.

B. THE MEU SLICE

1. Overview

The differences between a normal MPF operation and a MEU Slice specific operation occur during the arrival and assembly phase. The planning, marshaling, and movement phases are extremely similar independent of which module is being implemented. When a MEU Slice is employed, it involves only one ship from the MPSRON, normally the flagship. A secondary ship is designated backup and will be ready if the flagship is not available. The MEU Slice ship is loaded so that the necessary MPE/S can be offloaded with the minimal offload of other MPE/S. The equipment required for the MEU Slice is approximately 120 vehicles, as opposed to the entire load of 384 vehicles. It requires approximately 150 containers, as compared with the entire MPSRON's approximately 2,000 containers. (CRM 91-38, pp. D-6, E-2)

2. Arrival and Assembly

This is the phase where the full MEB MPF Operation and the MEU Slice MPF Operation differ mostly. For the full MEB Operation, the full MPSRON would be offloaded in a benign port with much of the material handling equipment provided by the Host Nation. The offload would most likely be pierside, with the added possibility of some MPE/S offloaded instream. For a MEU Slice offload, only part of one ship, normally the MPSRON flagship, will be offloaded. Additionally, Host Nation support can not be expected, so the entire offload must be accomplished using organic assets only. Organic assets include the ship's material handling equipment as well as the MEU Slice equipment. Additionally, as mentioned previously, the offload of a full MEB MPF will occur, by

doctrine, in a secure port. Experience has shown, as with OPERATION RESTORE HOPE in Somalia, that the port chosen for offload and throughput may not be totally secure. The MEU Slice offload and throughput will more likely be similar to OPERATION RESTORE HOPE than the totally secure port of OPERATION DESERT SHIELD that doctrine stipulates.

III. METHODOLOGY

A. SIMULATION

An MPF offload is not a serial process and cannot be easily modeled analytically. Many events occur simultaneously, such as crane operations aboard ship and LVS / RTCH operations ashore. Simulation was chosen as the modeling method, using the object oriented simulation language MODSIM II, in that it easily allows parallel events to occur.

Previous simulation models have looked at similar aspects of ship offloading. For example, one previous NPS thesis (Sumner, 1991) modeled container offload while another (Noel, 1993) considered only vehicles. While these theses were also concerned with total offload time, they were not strictly dependent on the organic offload assets. Noel's model did not consider containers, so the availability of RTCH's and LVS's was irrelevant, and Sumner's model examined a larger offload of two ships instream. Because the MEU Slice offload takes much less time than a multiple ship offload, it is much more sensitive to errors in assumptions. Therefore, this model has greater fidelity so that assumptions as to when the LVS's and RTCH's get ashore are unnecessary. Each specific piece of equipment is modeled, not just generic vehicles and containers. When an LVS or RTCH get ashore in this model, they become available to move and load containers.

In addition, to eliminate the requirement to develop a new model to study each aspect of MPF operations (or other similar transportation and mobility problems), the author, and others, developed a general transportation and logistics mobility modeling and analysis toolbox (discussed below) and the author developed a MEU Slice offload model as an extension to it. This extension provides the building blocks for unlimited future MPF modeling.

B. SMMAT - THE TOOLBOX

1. Description

The Simulated Mobility Modeling and Analysis Toolbox (SMMAT) is a collection of objects and processes designed to facilitate the modeling of a transportation and distribution network. Designed originally to handle problems as diverse as battle group vertical replenishment, maritime prepositioned ship offload, amphibious (LCAC) offload, and strategic sealift, it has the flexibility to handle large or small scale problems. The primary components of SMMAT are junctions, transporters, loaders, and cargo, and the functions provided to allow them to interact. Within SMMAT, cargo is moved between junctions by transporters, and is transferred between junction and transporters with loaders. Delivery can be determined by the route of the transporters, or can be determined strictly on the basis of cargo destination, with SMMAT choosing the transporter based on availability and compatibility with cargo, junction, and loader.

Additionally, all junctions have the ability to act as transporters and all transporters can act as junctions. This allows a transporter to receive and deliver cargo as it is transiting. For example, a ship transiting the ocean in a carrier battle group can resupply with helicopters from the supply ship. The ship is a transporter from port to port, but it is also a junction of the helocopter. This ability is accomplished through inheritence. In MODSIM II, when an object inherits another object, it receives all the capabilities of the inherited object. Specifically for SMMAT, junctions inherit transporters, so the junction receives all the capabilities of the transporter, plus the additional capabilities added for itself. Within SMMAT, all transporters are actually junctions functioning as tranporters. This allows junctions to move from junction to junction with the ability to have other junctions moving between them.

SMMAT provides several convenient ways to introduce variability into each problem, both during the creation of the scenario, and during the simulation itself. During the creation of the scenario, the number of pieces of cargo at each junction can be varied according to any number of statistical distributions. Additionally, any appropriate characteristic of the cargo (e.g., weight, size, volume, height) can be varied for each

individual piece using the same distributions. During the execution of the simulation, additional variability is possible by using distributions for load times for each piece of cargo, as well as by introducing reliability into the loaders and transporters, allowing them to break at random and be out of action for a variable repair time.

SMMAT also provides the capability to run replications of the scenario as specified by the user, collecting statistics on any parameter the user is interested in measuring. Upon completion of the replications, SMMAT also provides tools for statistical analysis of the total results.

2. Development

The need for a product like SMMAT was conceived by Professor Mike Bailey and Professor Bill Kemple of the Naval Postgraduate School in January 1994, in order to provide a product that would allow students to conduct thesis research on logistics problems on a larger scale than previously possible. SMMAT was developed under their guidance over a nine month period by LT Tim Wilson, USN, LT Ed Kearns, USN, LT Bill Roberts, USN, and the author. SMMAT was developed using MODSIM II® (CACI Products, 1993) on the UNIX workstations.

The development process followed a strict protocol prescribed by Prof. Bailey. First, each component had to meet the common requirements of the diverse applications being modeled by the developers. Additionally, each object and process was thoroughly tested prior to integration into the toolbox.

In order to create a framework allowing the creation of vastly different objects, a common data file structure was used, with special data handlers tailored to put the information contained in the data files into the proper fields of the object being created. Once a basic object has been instanciated; it inherits other attributes as is applicable to turn it into a final object capable of performing the required functions independently.

Interest in SMMAT resulted in an invitation to present at the 1994 CACI SummerSim Simulation Conference in Washington, D.C. in August, 1994, in which Professor Bailey and the four developers attended.

C. THE SCENARIO

For this simulation, a scenario was chosen in which a MEU Slice of the MPF would offload in support of a humanitarian assistance mission. A MAERSK class ship would offload instream and anchor approximately five miles from the beach. The setup ashore would vary as described in the Chapter I. Each COT ashore would be about five miles inland from the beach. The determination of which elements unload at each COT is a function of the setup options. All setup options are the same from the ship to the beach, with the differences becoming evident once ashore. The four options, as described earlier, are

- Option 1 - 1 COT with 2 RTCH's at the Beach.
- Option 2 - 1 COT with 2 RTCH's at the COT.
- Option 3 - 2 COT's with 1 RTCH at each COT and one at the Beach; the CE and GCE unload at COT1 and the CSSE and the ACE unload at COT2.
- Option 4 - 2 COT's with 1 RTCH at each COT and one at the Beach; the CE, GCE, and the CSSE unload at COT1 and the ACE unloads at COT2.

Specifics such as quantities, capacities, and sizes of transporters, loaders, and cargo will be discussed in detail in the following section.

D. THE MODEL FORMULATION

1. Junctions

Junctions are the center building blocks of SMMAT. The junctions contain other objects and allow them to interact. Each junction may contain numerous loading and unloading spots as well as lists of transporters, loaders, and cargo. The main mission of the junction is to control the flow of the transporters docked at it. Once the junction docks the transporter, it tells the transporter to unload, load, and depart.

a. Ships

One ship, from the MAERSK Class, forms the initial junction within this model. The ship has three unloading spots, one for each crane.

b. Beach Areas

The beach areas form the middle junction within this model. This is where control shifts from the Navy to the Marine Corps. Within this model, the beach will be modeled as one junction with one unloading spot.

c. Container Operations Terminals (COT's)

A COT is where all of the containers may be stored; within each COT, the containers are stored by MSE. Each COT will be modeled as an individual junction with one or two offload spots per COT, depending on the option being modeled.

2. Transporters

The transporters perform the bulk of the work once they are accepted by the junction. The transporter controls docking, unloading, loading, departing the junction, and transiting to the next junction. The next destination may be determined by either the transporter itself or the cargo it has loaded. Each transporter has a list of legal destinations to prevent the cargo from taking it to an illegal junction. This prevents, for example, lighterages from the sea from delivering cargo inland from the beach. Each transporter has a list of cargo that makes up that load as well as a field for average speed used to determine transit time.

a. Lightererages

The lighterages used in this model are organic to the one ship that is being offloaded. They will transport the cargo from the ship to the beach. The ship has eight causeways, three causeway sections, powered (CSP's) and five causeway sections, nonpowered (CSNP's). The causeways can be connected in various ways depending on loads to be carried, but every lighter must contain at least one CSP. The number of CSNP's is not limited. A combination of one CSP and two CSNP's would be called a 2+1

lighter, the "2" signifying the two CSNP's and the "1" signifying one CSP . For this model, the ships eight causeways will be formed into two 2+1 lighterages and one 1+1 lighterage. This configuration was chosen due to previous studies, which have found that making all causeway combinations as alike as possible reduces offload time (CRM 89-339, p. 40).

b. Logistics Vehicle Systems (LVS's)

The LVS's will initially be cargo until they arrive at the beach; once there they become transporters. The LVS's will transport the cargo from the beach to the COT's. With only seven LVS's being offloaded within this model, this is expected to cause chokepoints within the offload.

3. Loaders

The loaders are responsible for moving the cargo from the junction to the transporter. Each junction has a list of loader types and gives out loaders as the transporters ask for them. No cargo can be unloaded or loaded without first having a dedicated loader. Each type of loader has specific characteristics that make it unique, such as maximum load and average cycle time. In addition, each transporter and piece of cargo have lists of allowable loader types. These lists prevent, for example, forklifts from trying to load trucks and tanks onto lighterages.

a. Ship's Cranes

Since this model is of an instream offload, the ship's cranes will move all of the cargo from the ship to the lighterages. Each crane on the ship has a capacity of 30 Tons, which never was a factor in this model because it exceeded any cargo offloaded.

b. Rough Terrain Container Handlers (RTCH's)

The RTCH's will initially act as cargo until they reach the beach or specified COT, then they will be able to act as loaders. The RTCH's will move cargo from the lighterages to the beach, from the lighterages directly to awaiting LVS's, from the beach to the LVS's, and from the LVS's to the COT's. Since only the three RTCH's being

offloaded will be used, this is also expected to be a chokepoint and area of concern. The RTCH allocation is the driving force between the different setup options.

4. Cargo

The cargo is what drives the entire model, yet it is the simplest of all modules. When all of the containers have been delivered to the COT's, the simulation is complete. All cargo determined to be necessary for the MEU is initially loaded onto the ship before the simulation begins. To model the conflict between vehicles and containers for lighterage space, all vehicles and containers are delivered from the ship to the beach. Once at the beach, the delivery of containers to the COT's is considered independent of, and more time critical than, the delivery of the vehicles to the AAOE's. Therefore, the delivery of vehicles to the AAOE's is assumed to be not necessary and is not modeled in this simulation. Once the vehicles arrive at the beach, they are removed from the beach's cargo list and are not considered for delivery inland.

The cargo is being brought into the model with the help of the Computer Aided Embarkation Management System (CAEMS), a sub-system of MAGTF II Logistics Automated Information System (LOG AIS). The notional cargo list, with offload priorities and cargo characteristics, used in this thesis was determined from the analysis of the *1stLt Jack Lummus* load plans (a MAERSK-Class ship from MPSRON-3), and from the recommended changes provided in CMR 91-38, *Reconfiguration of MPSRon-3 To Support The Priority Force Modules.* See Appendix A, the listing of the data files used in the simulation, for the detailed cargo data used; it is provided in the files *simstart.dat* and *cargo.dat*.

5. Randomness

Randomness enters into simulations when the attempt is made to model the real world. In this model, all processes that could be realistically modeled with distributions were so modeled, others were modeled deterministically with the best data available.

a. *Loading, Unloading, and Transit Times for the lighterages*

The Center for Naval Analyses (CNA) has analyzed MPF operations extensively from the beginning. They have determined through analysis of previous operational results, that the loading, unloading, and transiting of lighterages follow lognormal distribution with varying parameters, dependent upon ship class and distances from the beach (CRM 91-3, p. 26). For this model, the distributions provided for the loading and unloading of the lighterages were used, with slight modifications, but the transit distribution was not. The only drawback to using the distributions for loading and unloading is that they aggregate the individual cargo into one large piece of cargo per lighterage. The entire lighterage cargo list is loaded or unloaded at the exact same time. This is not to the level of detail initially planned for this model. This proved to not be a problem for the loading of the lighterages at the ship, because the lighterage could not leave the ship until it is full anyway. No realism is lost by aggregating at this point.

Realism would be lost, however, by offloading at the beach in aggregate. If aggregation was used, numerous pieces of cargo would arrive at the beach simultaneously for dispersion rather than serially as each lighterage offloaded. It was decided that a separate unload time for each piece of cargo was needed. In order to have the lighterage offload times follow the lognormal distribution provided, and still unload each of **n** pieces of cargo in a distinct, random length of time, random offload times were generated as follows:

First, a total lighterage offload time, X, was generated from the lognormal distribution.

Next, **n** U[0, 1] random variables, U_1, U_2, ..., U_n, were generated. These were rescaled to form Z_1, Z_2, ..., Z_n by letting

$$U = \sum_{i=1}^{n} U_i \text{ and } Z_i = \frac{U_i}{U} \text{ so } \sum_{i=1}^{n} Z_i = 1.$$

Finally, the individual offload times were formed as

$$X_i = Z_i \times X,$$

so

$$\sum_{i=1}^{n} X_i = X.$$

Once the offload time of each individual piece of cargo was found, these new times were used to determine when each individual piece of cargo was offloaded. This allowed the RTCH access to the cargo sooner than would otherwise have been possible, and added a measure of increased realism to the model.

The parameters of the lognormal distribution for transit time were based upon the specific exercise being modeled. The scenario used in this model was not close enough to any of the observed exercises for the author to comfortably use the associated distributions. It was determined that it would be better to model the transit time deterministically, with different parameters for full and empty loads.

b. Loading, Unloading, and Transit Times for the LVS's

The loading, unloading, and transiting times of the LVS's were not as easily accessible as the lighterage data.

The loading and unloading of the LVS's were determined by the author to be factors of the RTCH, and not of the LVS itself. These were both modeled with the same distribution, U ~ Uniform [4, 12], where the parameters are in minutes. This distribution is based on the authors experience and on Sumner's thesis (1991), and it seems to satisfy common sense. Firstly, one would expect the loading of the LVS to take a minimum amount of time, no matter where the container is located in the staging area. Secondly, one would expect that the loading would take no longer than a certain time, no matter where the container was located in the staging area. Thirdly, one would expect the containers to be uniformly distributed throughout the staging area. Therefore, a uniform distribution is called for. One could possibly dispute the parameters, but by no more than a minute or so either way, and the author does not feel that this would alter the simulation results significantly.

Since no recently published data was available for the transiting of LVS's, it was modeled deterministically with the same parameter for full and empty loads.

c. *Failure and Repair Times*

It is necessary to model failure and repair times because they occur in the real world. Not modeling them will most likely give overly optimistic results from the simulation. For the simulation to reveal meaningful results, the reliability input into the model needs to be accurate. Determining the reliability for the different parts of this simulation was difficult. Since most models of MPF operations have stopped at the beach, the author could not find trustworthy reliability data for the LVS and the RTCH from MPF operations, the reliability data used would have to come from a different source.

The Marine Corps keeps detailed maintenance records of all its equipment, but it does not provide accurate reliability data. Even though fields exist on the Equipment Record Orders (ERO's) for mileage, hours, or rounds at the time of breakdown, no requirement exists that this field be filled in accurately. Therefore, it normally is filled with "dummy" numbers, such as <u>00000</u> or <u>99999</u>. Trying to use this information would yield nonsense at best.

The next best solution for reliability information for the LVS and RTCH was to use the results from the systems' operational test (OT) performed before procurement of the items. These numbers show how well the systems performed under various conditions and levels of duress. The disadvantages of this solution are twofold: (1) very few samples were used for the initial OT's and (2) this reliability represents a new system, not a system that has been in operation for a number of miles or hours.

Another possibility is to use availability data from OPERATION DESERT STORM. The advantages of using this data is that it represents units that were deployed in an actual operation. Additionally, the data is available for all the units that took part in Desert Storm, a very large sample to get data from. The disadvantages are that this information is provided in availability form only and it does not represent equipment that has been in storage, as the MPF equipment has been. Even with these disadvantages, it was determined that this information was the best available. In order to

use this availability data, assumptions about Mean Time to Repair (MTTR) would have to be made.

The worst LVS availability in OPERATION DESERT STORM was 93% while the worst RTCH availability was 64% (CRM 91-206, pp. 8, 18, and 36). Using the basic Availability formula of

$$A = \frac{MTBF}{MTBF + MTTR},$$

the MTBF of the LVS is 13.29 times its MTTR and the MTBF of the RTCH is 1.78 times its MTTR. The RTCH availability from OPERATION DESERT STORM is not consistent with previous studies, so RTCH reliability was not treated within this thesis (Sumner, p. 39, 1991). This decision will most likely give optimistic results, but should still allow for the accurate comparison of times among different options. One day was estimated by the author as the MTTR for the RTCH. Both 93% and 100% availability were looked at within the model; 100% was used as a baseline with 93% being a lower bound as to what to expect. Both MTTR and MTBF were modeled using the exponential distribution with 1 day as the parameter for MTTR and 13.29 days as the parameter for MTBF.

6. Data instantiation

The tools used to instantiate the initial data within this model are part of SMMAT. Six data files are necessary for this toolbox to work. One file is written for the junctions, *junct.dat*, one for the transporters, *trans.dat*, one for the cargo, *cargo.dat*, and one for the loaders, *load.dat*. These files contain the static information about each module. Additionally, another file, *simstart.dat*, is written that explains the dynamic relationships of the modules. It lists each junction with its associated lists of transporters, cargo, and loaders. The final data file needed is a list of primary junctions, *pjname.dat*. A primary junction is a junction which does not belong to a larger junction. In the case of this model, the primary junctions are the ship, the beach, and the COT's. These primary junctions are listed in both the primary junction file and in the junction data file. The Lighterages and LVS's are listed in the transporter data file, the cranes and RTCH's are listed in the loader data file, and all of the cargo in its detail is listed in the cargo.dat file. The dynamic data

file includes the ship with its associated transporters, cargo, and loaders. See Appendix A to view the actual files used for this model.

IV. DATA COLLECTION AND ANALYSIS

A. BACKGROUND

The experiment for this thesis was conducted as a 2 x 4 full factorial design. Thus, the simulation model was used to generate data for each of the eight configurations that resulted from four setup options and two reliability levels. Each run produced 30 replications. The data collected from these runs is included in Appendix B. Table 1 is a listing of the mean values from the eight design settings, along with the column means, row means, and the grand mean.

TABLE 1. SETUP OPTIONS / RELIABILITY MEAN VALUES

	Option 1	Option 2	Option 3	Option 4	Row Means
100 % Rel	5,125.32	5,117.36	5,151.04	5,154.11	5,139.96
93 % Rel	5,155.37	5,159.8	5,224.23	5,109.7	5,162.28
Column Means	5,140.34	5,138.58	5,187.64	5,131.91	**5149.62**

The data will first be analyzed with a two-factor Analysis of Variance (ANOVA). If factor effects are found to be significant, further study will be done to identify those differences. If no significant factor effects can be found, further analysis will be conducted to look for trends that may indicate possible effects or areas for further study.

B. RELIABILITY LEVEL / SETUP OPTION ANALYSIS

1. Analysis of Variance (ANOVA)

ANOVA was used as to test the significance of reliability level and setup option. A two-way ANOVA was conducted with the reliability at two levels, 100% and 93%, the setup options at four levels, one for each candidate setup previously mentioned,

and each cell containing 30 values, one per replication. ANOVA is an especially useful technique that attempts to attribute the variance in the observations by the level of the factors. A basic assumption in order to use ANOVA is that each observation can be expressed as

$$X_{ijk} = \mu + R_i + SO_j + I_{ij} + \varepsilon_{ijk},$$

for $i = 1, 2$; $j = 1, 2, 3, 4$; and $k = 1, 2, \ldots, 30$.

X_{ijk} is the k^{th} observation in cell ij,

μ is the overall mean,

R_i is the effect due to Reliability,

SO_j is the effect due to the Setup Option,

I_{ij} is the effect due to the interaction of R_i and SO_j, and

ε_{ijk} is the random error of the k^{th} observation in cell ij.

ε_{ijk} is normally distributed with mean equal 0 and variance equal σ^2. Additionally, it is usually assumed that

$$\sum_{i=1}^{2} R_i = 0, \ \sum_{j=1}^{4} SO_j = 0, \ \sum_{j=1}^{4} I_{ij} = 0 \text{ for } i = 1, 2, \text{ and } \sum_{i=1}^{2} I_{ij} = 0 \text{ for } j = 1, 2, 3, 4.$$

The hypothesis for the existence of a reliability effect is

$H_o : R_i = 0 \ \forall \ i$ (there is no reliability effect)

$H_a : R_i \neq 0$ for some i (there is a reliability effect),

for the setup option effect it is

$H_o : SO_j = 0 \ \forall \ j$ (there is no setup option effect)

$H_a : SO_j \neq 0$ for some j (there is a setup option effect),

and for the interaction effect it is

$H_o : I_{ij} = 0$ " i and j (there is no interaction effect)

$H_a : I_{ij} \neq 0$ for some i and j (there is an interaction effect).

Table 2 contains the results of the ANOVA. When using ANOVA, one should test for the interaction effect first; if the interaction effect is significant, no other tests should be done. Since the F- Statistic of the interaction, 0.2841, is less than the critical $F_{3,\infty\,0.1}$, 2.08, the null hypothesis for the interaction cannot be rejected. Infinite denominator degrees of freedom were used for the preceding critical F due to constraints in the F - Table. If a statistic cannot be rejected with infinite degrees of freedom, it will not be rejected for any degree of freedom selected for that parameter. Therefore, <u>no interaction effect exists</u>. Now, testing for reliability and the setup options effects can occur. Since the residual had 232 degrees of freedom, pooling with the interaction to gain fidelity was not necessary. The F- Statistic of the reliability, 0.3226, and the F - Statistic of the setup options, 0.3598, are both less than their respective F critical values, 2.17 and 2.08, so neither null hypothesis can be rejected. It cannot be shown that an effect due to the reliability or setup options exists.

TABLE 2. TWO WAY ANOVA FOR SETUP OPTIONS / RELIABILITY

Source	Degrees of Freedom	Sum of Squares	Mean Square	F - Statistic
Reliability	1	38,429	38,429	0.3226
Setup Options	3	128,562	42,854	0.3598
Interaction	3	101,516	33,839	0.2841
Residual	232	27,635,664	119,119	
TOTAL	239	27,904172		

2. Graphical Analysis

Boxplots provide another method to see if a factor is different from the rest, as well as determining certain attributes about the data. These attributes include the median of the data, the upper and lower interquartiles of the data, the outliers, and symmetry to name a few. The boxplot allows multiple runs to be compared simultaneously, from all

eight, to four when the data is pooled by setup option, to two when the data is pooled by reliability level. (Chambers, and others, 1983, pp. 21-24)

The full boxplot for this experiment, Figure 1, contains eight separate plots, one for each setup option at each reliability level. From this plot, one can see that no significant difference exists between any of the eight samples. The confidence intervals, the inner box within each larger box, overlap so that all eight groups contain similar points. This is another way of showing no difference between groups. Additionally, a few of the groups are slightly skewed, but not so as to provide any useful information about the data.

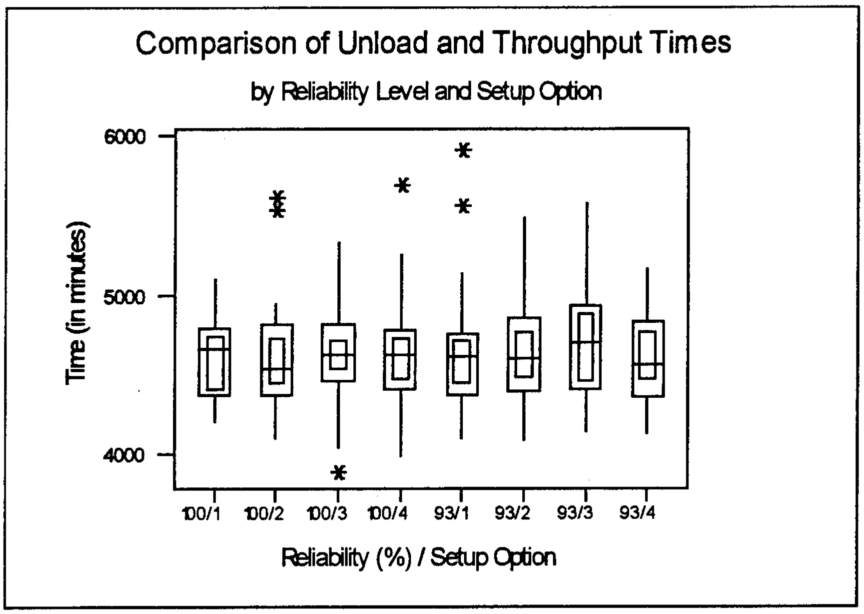

Figure 1. Boxplot of the Individual Simulation Runs

C. SETUP OPTION ANALYSIS

The setup option graphical analysis was conducted using a pooled boxplot, Figure 2, with four plots. This allows for the comparison of setup options without reliability, assuming reliability is not significant. From the ANOVA, since it cannot be shown that reliability is a significant factor, this was a valid assumption. Nothing on this boxplot seems to be meaningful. As noted above, the confidence intervals all contain similar points

so no significant differences in times can be found. The pooling by setup option did not show any relationships previously hidden by the data.

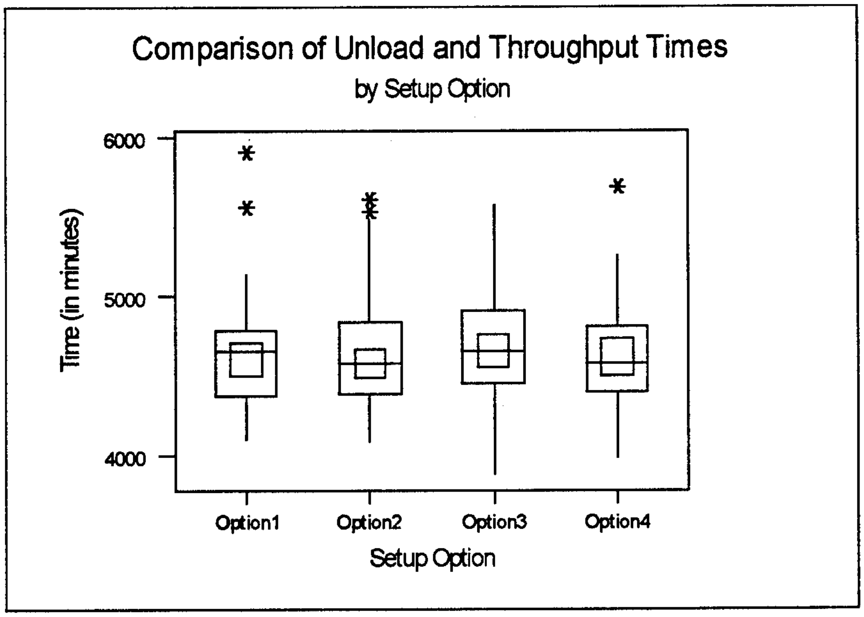

Figure 2. Boxplot of the Simulation Runs, Pooled by Setup Option

D. RELIABILITY LEVEL ANALYSIS

1. Graphical Analysis

The graphical analysis of the reliability levels was conducted using a pooled boxplot, Figure 3, with two plots. This allows for the comparison of reliability only with setup option assumed to be not significant. As with the previous plot, the ANOVA conducted earlier verifies the assumption that setup option is not significant. Again the confidence intervals overlap so no significant differences can be found between the two reliabilities. This result is somewhat surprising given the MTTR and MTBF used in the model.

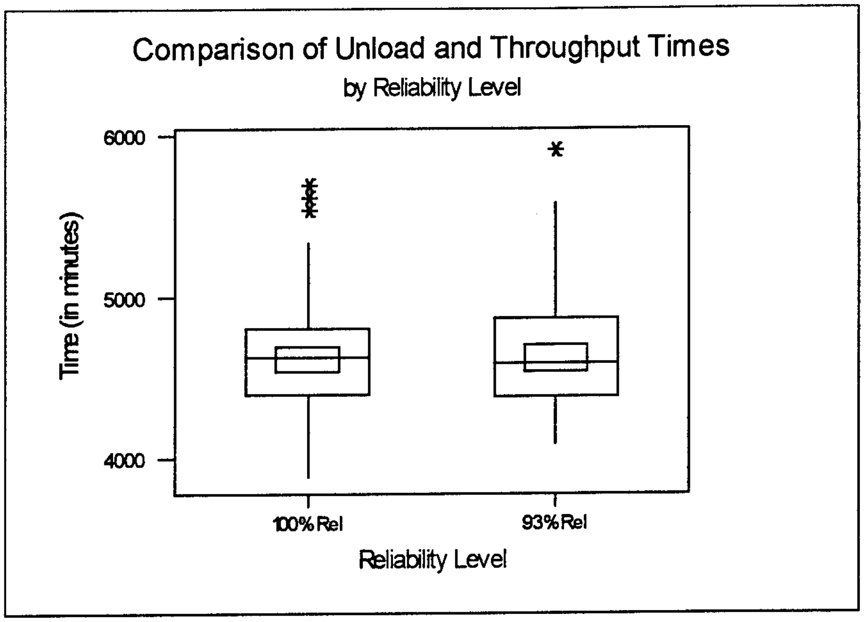

Figure 3. Boxplot Results of the Simulation Runs, Pooled by Reliability Level

Using the assumed MTBF of 13.29 days (or 19,137.6 minutes) and the assumed exponential failure and repair times, the probability that a specific LVS survives past the grand mean without failure is approximately equal to

$$P(X > \text{Grand Mean}) = P(X > 5149.62) = (e^{-\frac{5149.62}{19137.60}}) = 0.764\,.$$

Therefore, the probability that all seven LVS's survive past the grand mean is equal to

$$P(\text{all 7 LVS's survive}) = [P(\text{a specific LVS surives})]^7 = (0.764)^7 = 0.152\,.$$

Assuming that the operation length is equal to the grand mean mentioned above, 0.152 also equals the probability that all seven LVS's survive an operation. Theoretically, this shows that the simulation runs the same at 100% and 93% reliability only 15.2% of the time. Almost 85% of the time, the simulation at 93% reliability was running with less LVS's than the 100% reliability simulation. Analysis of the simulation output shows the LVS's were indeed breaking down when set at 93% reliability with about one of the seven

reaching its failure time before the simulation ended. One could possibly conclude from these results that the LVS's are not taxed enough in this scenario. The loss of one or two LVS's for a short time does not seem to slow the system down as expected.

2. Differences in the Mean

In addition to the graphical analysis just discussed, the method of pairwise differences can be used to test for significant differences due to reliability. This method is useful because it exploits dependence in the data (e.g. due to setup option effect) to reduce variance, thus gaining precision. See Appendix C for a listing of differences in time by reliability level for each setup option. Assuming the difference are normally distributed, the following hypothesis test can be used:

$$\text{Ho: } \mu_{R(100)} - \mu_{R(93)} = \mu_d = 0$$

$$\text{Ha: } \mu_{R(100)} - \mu_{R(93)} = \mu_d \neq 0,$$

where

$\mu_{R(100)}$ is the mean value of time at 100% reliability,

$\mu_{R(93)}$ is the mean value of time at 93% reliability, and

μ_d is the difference between them.

The test statistic used for this test is Student's t statistic,

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} \quad ,$$

where the null hypothesis will be rejected if $|t|$ is greater than the critical t from the tables. (Mendenhall, Wackerly, and Scheaffer, 1990, pp. 573-575) For this problem,

$\bar{d}$, the sample average of the differences, equals -25.26,

s_d, the sample standard deviation of the differences, equals 475.223, and

n, the number of samples, equals 120.

This gives t = -0.58227, which results in a two-sided p-value of 0.5687, and leads to a failure to reject the null hypothesis. Therefore, it cannot be shown that a difference exists

between $\mu_{R(100)}$ and $\mu_{R(93)}$. If no difference exists between the means, then it cannot be shown that reliability tested here has an effect on total offload time.

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

1. SMMAT

The Simulated Mobility Modeling and Analysis Toolbox (SMMAT) was developed and built by faculty and students of the Naval Postgraduate School, including the author. It is designed to provide students interested in modeling transportation and distribution problems with a basic toolbox of object oriented computer modules on which more specific thesis related simulations could be built.

SMMAT proved to be extremely useful as the toolbox on which the author's MEU Slice Model was built. Once completed, it provided the author with a steady base on which to then produce a more specific model. SMMAT's overall usefulness was not taken advantage of within this thesis. As much as 90% of the time spent writing computer code for this thesis was spent on SMMAT. Future users of SMMAT will not have that burden. They will be able to take SMMAT and use it from the start. With this powerful modeling toolbox now available, they will then be able to study more difficult problems in much more detail.

2. The MEU Slice Model

An MPF employment is a very delicately balanced operation including elements of many organizations. The operation can go awry at any time, from the initial planning phase through the marshaling and movement phases to the arrival and assembly phase. At no time during this extremely busy operation, is it more hectic than during its final phase, the arrival and assembly. It is during this phase that the marriage of Marines and their equipment must occur.

Of all MPF employments, the one most critical to time is the MEU Slice force module. The MEU Slice allows for the offload of a partial ship in order to support a MEU

ashore. For this force module, the equipment and supplies must be ashore as rapidly as possible, but it must be accomplished with only organic lighterages afloat and minimal RTCH's and LVS's ashore.

The most crucial phase, the arrival and assembly, of this most time sensitive force module, was looked at in this thesis. Specifically, the instream offload, was examined as the worst case possible. Different setups ashore were examined in order to determine if these setup options affected the offload and throughput process. Additionally, two levels of LVS reliability were examined to see if that too was a factor.

From the eight experiments run, four setup options at two reliability levels each, using the assumptions and parameters previously listed., it was determined that there were no significant differences between the setup options or reliability levels, or any significant interaction between the two. This is not what the author was anticipating. The model did not bring out the expected difference. There are four possible explanations for this.

- The model is not doing what it is supposed to do.
- The assumptions and parameters are incorrect.
- The model does not have enough fidelity to capture the effects between the RTCH's and the LVS's.
- The author could be wrong.

A detailed analysis of the simulation output has verified that the model does indeed do what it is supposed to do. This eliminates the first alternative from above as a possibility. It is not as straight forward a process to reach a conclusion on the second and third alternatives. After rechecking the assumptions and parameters used within the model, the author has concluded that 100% RTCH reliability may not be a valid assumption. Other assumptions, however, such as lighterage reliability and transit times, do seem valid. Although they play a part in the overall simulation results, they are relatively constant for all setup options, and do not effect which setup option produces the quickest offload.

Another possibility, that not enough fidelity exists within the model, can only be confirmed by actually increasing the fidelity and comparing the results. The fourth alternative, that the author's intuition was incorrect, is a definitely possibility. This can be determined after the first three alternatives are eliminated. The following recommendations for further study are offered so that the final three alternatives can be examined more closely.

B. RECOMMENDATIONS

1. SMMAT

In the process of utilizing SMMAT to develop the MEU Slice Model, a few areas for future refinement were determined. As mentioned earlier, within SMMAT, junctions inherit transporters. Using this same concept, the author recommends the inheritance structure shown in Figure 4.

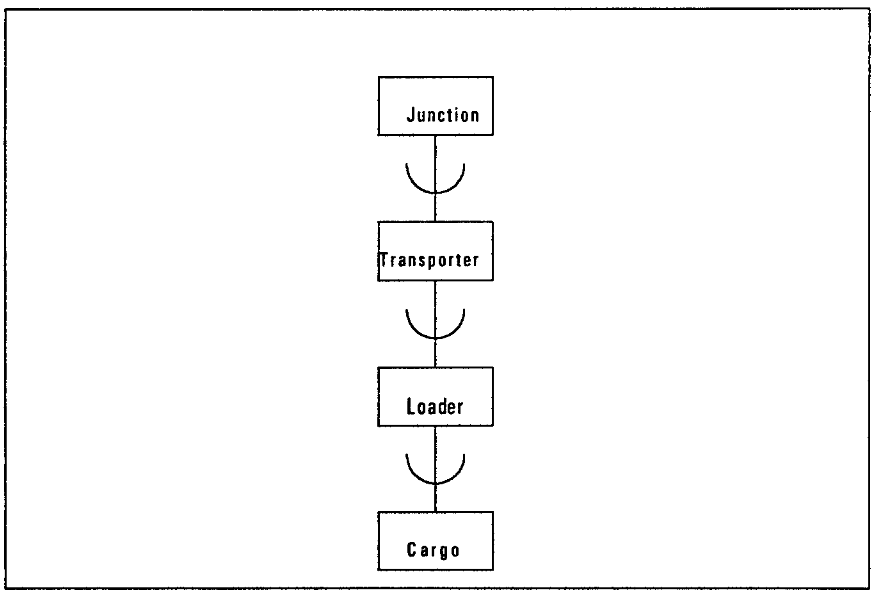

Figure 4. Recommended SMMAT Inheritance Structure

This structure puts the cargo as the lowest entity within SMMAT. Every loader will inherit cargo, so they have the capability to be carried as well as to carry. All transporters

will inherit loaders, so each transporter has the capability to load and unload itself, as well as to transit. Each junction will continue to inherit a transporter, so it can receive cargo as well as deliver it. Without the use of this structure, the author was forced to create an LVS cargo for the ship and then create a new LVS transporter once the LVS cargo reached the beach, and then dispose of the LVS cargo. This new structure will allow an LVS to be carried on a ship as a piece of cargo and then seamlessly act as a transporter once it hits the beach.

2. The MEU Slice Model

Additional RTCH's could be added to the model and new, untried setups could be modeled. This would be quite beneficial, since there is presently debate within the Marines Corps as to whether there are adequate RTCH's within each MSPRON (Pleis, January 1993, pp. 19 - 21).

Within the MEU Slice model, fidelity could be increased with the results of both models being compared to see if a difference exists. If the new SMMAT structure is adopted, it would be quite easy to model the RTCH as a transporter with loader capabilities. This would give much more fidelity to the beach operations. It would allow the RTCH to transit, and load and unload at junctions. A whole sub-system could be modeled at the beach at a level of fidelity greater than the rest of the model. This would be useful because the beach is where the critical interaction occurs and crucial decisions are made.

RTCH reliability should be taken into account once more reliable figures are determined. Additionally, the following could be included to reduce the assumptions in the model and to add more realism to the scenario.

- RTCH loading and unloading also needs to monitored closely so that they can better be modeled in future simulations. Experience is always useful, but not always available.

- Crane and lighterage reliability; the cranes and lighterages were assumed to never break down, but this was overly optimistic.

- Lastly, LVS transit distributions could add additional realism if accurate distributions could be determined.

The results of this new model should also be compared to the original results to see if a difference exists. If the results, after increased fidelity and fewer assumptions, show a difference between setup options, then the author's intuition was correct. If no difference occurs, then the fourth alternative listed previously must be correct, that the author was wrong in his intuition and there is no difference between setup options.

APPENDIX A - INPUT DATA FILES

PJNAME.DAT

```
1 # number of records in this file
# This is the MASTER data file that contains the
#  names of the Primary Junctions,
#   Names should agree with the JUNCT.DAT
Master ->
LUMMUS  # junction 1
BEACH   # junction 2
COT1    # junction 3
COT2    # junction 4
COTNSE  # junction 5
\\
```

JUNCT.DAT

```
11 # number of records in this file
# This is the junction data file,
#  names should agree with PJNAME.DAT
LUMMUS ->
LUMMUS    # Name : STRING;
# { Location : LocationRecType;}
0       # {X coordinate}
0       # {Y coordinate}
3      # NumSpots : INTEGER;
\\

BEACH ->
BEACH     # Name : STRING;
# { Location : LocationRecType;}
5.0       # {X coordinate}
0.0       # {Y coordinate}
1     # NumSpots : INTEGER;
\\

COT1 ->
COT1      # Name : STRING;
# { Location : LocationRecType;}
10       # {X coordinate}
2        # {Y coordinate}
2 # (1 or 2) # NumSpots : INTEGER;
\\

COT2 ->
COT2      # Name : STRING;
# { Location : LocationRecType;}
10        # {X coordinate}
-2        # {Y coordinate}
1 # (or 2) # NumSpots : INTEGER;
\\

COTNSE ->
COTNSE     # Name : STRING;
# { Location : LocationRecType;}
10          # {X coordinate}
0          # {Y coordinate}
1          # NumSpots : INTEGER;
\\
```

TRANS.DAT

```
3 # number of records in this file
# This is transporter data file.
LIGHTER(1+1) ->
# ------- Capacity of the transporter ------
3523.0 # SqFt
       # SqFtTall
340000.0 # Weight
100000000000.00 # Volume
8 # Number
# -------------------------------------------------#
\\

LIGHTER(1+2) ->
# ------- Capacity of the transporter ------
5224.0 # SqFt
# SqFtTall
540000.0 # Weight
100000000000.00 # Volume
13 # Number
# -------------------------------------------------#
\\

*LVSLONG ->
# ------- Capacity of the transporter ------
100000000.0 # SqFt
# SqFtTall
100000000.0 # Weight
100000000.0 # Volume
3 # Number
# -------------------------------------------------#
\\
```

CARGO.DAT

```
25 # number of records in this file
 # This is the cargo "type" fixed data file
CONTAINER ->
# Size : CapRecType;
33     # SqFt      # SqFtTall
8980   # Weight
279    # Volume
1      # Number
\\

HMMWV ->
# HIGH MOBILITY MULTI-WHEELED VEHICLE
# (D1158, D1159, D1180, A1930, A1935, A1955)
# Size : CapRecType;
110    # SqFt      # SqFtTall
6104   # Weight
 632   # Volume
1      # Number
\\

HMMWVLONG ->
# HMMWV W/ TRAILER (D0085)
# Size : CapRecType;
166    # SqFt      # SqFtTall
 8304  # Weight
195    # Volume
1      # Number
\\

LINECHARGE ->
# LINECHARGE LAUNCHER (B1298)
# Size : CapRecType;
47     # SqFt      # SqFtTall
3800   # Weight
284    # Volume
1      # Number
\\

LVSLONG -> #  (D0877, D0878, D0879, D0881)
# LVS (D0209) W/ TRAILER
# Size : CapRecType;
320    # SqFt      # SqFtTall
43400  # Weight
2165   # Volume
1      # Number
\\

*LVSLONG ->
# LVS (D0209) W/ TRAILER (D0876)
# {This is the Container Hauler!!!}
# Size : CapRecType;
320    # SqFt      # SqFtTall
43400  # Weight
2165   # Volume
1      # Number
\\

LVSLOWBED ->
# LVS (D0209) W/ LOW BED TRAILER (D0235)
# Size : CapRecType;
596    # SqFt      # SqFtTall
62987  # Weight
3280   # Volume
1      # Number
\\

FIVETON ->
 # 5 - TON TRUCK (D1059, D1134)
# Size : CapRecType;
209    # SqFt      # SqFtTall
23700  # Weight
1811   # Volume
1      # Number
\\

FIVETONLONG ->
# 5-TON TRUCK (D1059, D1134) W/ TRAILER
# Size : CapRecType;
334    # SqFt      # SqFtTall
29580  # Weight
2310   # Volume
1      # Number
\\

REFUELER ->
# SEMI-TRAILER REFUELER (D0215)
# Size : CapRecType;
244    # SqFt      # SqFtTall
16190  # Weight
2135   # Volume
1      # Number
\\

AAV -> # (E0846, E0856)
# AMPHIVIOUS ASSAULT VEHICLE
# Size : CapRecType;
311    # SqFt      # SqFtTall
46720  # Weight
3264   # Volume
```

1 # Number
\\

SHOP_EQUIP ->
SHOP EQUIPMENT, CONTACT (B1945)
Size : CapRecType;
127 # SqFt # SqFtTall
9360 # Weight
872 # Volume
1 # Number
\\

SCRAPER ->
SCRAPER-TRACTOR, WHEELED (B1922)
Size : CapRecType;
472 # SqFt # SqFtTall
63900 # Weight
5538 # Volume
1 # Number
\\

COMPRESSOR ->
AIR COMPRESSOR (B0395)
Size : CapRecType;
134 # SqFt # SqFtTall
7480 # Weight
867 # Volume
1 # Number
\\

TRACTOR ->
TRACTOR , RT, ARTICULT (B2567)
Size : CapRecType;
193 # SqFt # SqFtTall
35840 # Weight
2122 # Volume
1 # Number
\\

FIRETRUCK -> # (D1082)
Size : CapRecType;
121 # SqFt # SqFtTall
8160 # Weight
764 # Volume
1 # Number
\\

GRADER ->
GRADER, ROAD, MOTORIZED (B1082)
Size : CapRecType;
216 # SqFt # SqFtTall
31140 # Weight
2284 # Volume
1 # Number
\\

RTCH -> # B0391
CONTAINER HANDLER, ROUGH TERRAIN
Size : CapRecType;
403 # SqFt # SqFtTall
106660 # Weight
5568 # Volume
1 # Number
\\

FORK_EXT ->
TRUCK, FORKLIFT, EXT (B2561)
Size : CapRecType;
224 # SqFt # SqFtTall
27360 # Weight 1878 # Volume
1 # Number
\\

FORK_RT -> # (B2566)
TRUCK, FORKLIFT, ROUGH TERRAIN
Size : CapRecType;
107 # SqFt # SqFtTall
11180 # Weight
699 # Volume
1 # Number
\\

LAV ->
LIGHT ARMORED VEHICLE (E0942)
Size : CapRecType;
171 # SqFt # SqFtTall
25440 # Weight
1757 # Volume
1 # Number
\\

WELDER ->
WELDING MACHINE, ARC (B2685)
Size : CapRecType;
124 # SqFt # SqFtTall
7140 # Weight
910 # Volume
1 # Number
\\

HOWITZER ->
HOWITZER, MEDIUM (E0665)

```
# Size : CapRecType;
212    # SqFt      # SqFtTall
16460  # Weight
1484   # Volume
1      # Number
\\

WATER_DIST ->
# TACTICAL WATER DISTRIBUTOR (B2391)
# Size : CapRecType;
141    # SqFt      # SqFtTall
4540   # Weight
1010   # Volume
1      # Number
\\

EMI_SHELTER ->
# SHELTER, 10 FT, EMI (A2335)
# Size : CapRecType;
80     # SqFt      # SqFtTall
5600   # Weight
640    # Volume
1      # Number
\\
```

LOAD.DAT

```
2 # number of records in this file
# This is the loader data file
CRANE ->
CRANE    # Name       : STRING;
# Capacity   : CapRecType;
1000000.0      # SqFt       # SqFtTall
10000000.0     # Weight
10000000.0     # Volume
1        # Number
# Size of loader  : CapRecType;
1      # SqFt       # SqFtTall
1        # Weight
1        # Volume
1        # Number
\\

RTCH ->
RTCH     # Name       : STRING;
# Capacity   : CapRecType;
1000000.0      # SqFt       # SqFtTall
100000.0       # Weight
100000.0      # Volume
1      # Number
# Size of loader  : CapRecType;
1      # SqFt       # SqFtTall
1        # Weight
1        # Volume
1        # Number
\\
```

SIMSTART.DAT

```
8 # number of records in this file
# This is the DYNAMIC data file
LUMMUS ->
28  # Number of Cargo "Types"
# {The cargo type must be defined in cargo.dat.}
2  # Number of Trans "Types"
#  {The trans type must be defined in trans.dat.}
1  # Number of Load  "Types"
# {The load  type must be defined in  load.dat.}
# **********************
# ***CARGO LIST STUFF***
# **********************
#$$$$ 1st Cargo Stuff $$$$
 #$$$$$$$$$$$$$$$$$$$$$$$$$$
 CONTAINER # 1st kind of cargo in cargo list
21       # Number of 1st kind
# NAME    PRIORITY
CONTMRE1  2  # # MGCE
CONTMRE2  4  # # MGCE
CONTMRE3  8  # # MGCE
CONTMRE4  6  # # MGCE
CONTMRE5  18 # # MGCE
CONTMRE6  1  # # MGCE
CONTMRE7  17 # # MGCE
CONTMRE22  16 # MCE
CONTMRE23  8  # MCE
CONTMRE24  21 # MCE
CONTMRE25  17 # MCE
CONTGENL41 10 # # MGCE/MCE
CONTGENL42 35 # # MGCE/MCE
CONTGENL43 25 # # MGCE/MCE
CONTGENL44 36 # # MGCE/MCE
CONTGENL45 31 # # MGCE/MCE
CONTGENL46 26 # # MGCE/MCE
CONTGENL47 26 # # MGCE/MCE
CONTGENL48 10 # # MGCE/MCE
CONTGENL49 35 # # MGCE/MCE
CONTGENL50 25 # # MGCE/MCE
 3          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH  # STAGINGAREA   # ...
COT1        # Nth Junction in Junction Path
#$$$$ 2nd Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$
 *LVSLONG      # 2nd kind of cargo in cargo list
 7          # Number of 2nd kind
# NAME    PRIORITY
 *LVS1   1    # 1st Name, Priority of 1st Cargo
*LVS2  2   # Nth Name, Priority of Nth Cargo
*LVS3  3
*LVS4  4
*LVS5  5
*LVS6  6
*LVS7  7
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$$ 3rd Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$
 RTCH    # 2nd kind of cargo in cargo list
3        # Number of 2nd kind
# NAME    PRIORITY
RTCH1  1 #  # MEU
RTCH2  2 #  # MEU
RTCH3  3 #  # MEU
 2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
 #$$$$ 4th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$
 HMMWV  # 2nd kind of cargo in cargo list
 103           # Number of 2nd kind
# NAME    PRIORITY
HMMWV19  1   # MEU
 HMMWV20  5   # MEU
HMMWV21  23  # MEU
HMMWV22  43  # MEU
HMMWV23  49  # MEU
HMMWV24  54  # MEU
HMMWV25  58  # MEU
HMMWV26  60  # MEU
HMMWV27  84  # MEU
HMMWV28  86  # MEU
HMMWV29  87  # MEU
HMMWV30  88  # MEU
HMMWV35  20  # MEU
HMMWV36  25  # MEU
HMMWV37  26  # MEU
HMMWV38  76  # MEU
HMMWV39  107 # MEU
HMMWV40  125 # MEU
HMMWV41  130 # MEU
HMMWV42  133 # MEU
HMMWV43  134 # MEU
HMMWV44  135 # MEU
HMMWV45  137 # MEU
HMMWV46  138 # MEU
```

```
HMMWV47  139 # MEU
HMMWV48  141 # MEU
HMMWV49  142 # MEU
HMMWV50  143 # MEU
HMMWV51  145 # MEU
HMMWV52  146 # MEU 30
HMMWV53  147 # MEU
HMMWV54  148 # MEU
HMMWV55  149 # MEU
HMMWV56  150 # MEU
HMMWV57  3  # MGCE
HMMWV58  14  # MGCE
HMMWV59  18  # MGCE
HMMWV60  18  # MGCE {ON PURPOSE}
HMMWV61  19  # MGCE
HMMWV62  21  # MGCE 40
HMMWV63  22  # MGCE
HMMWV64  24  # MGCE
HMMWV65  25  # MGCE
HMMWV66  27  # MGCE
HMMWV67  28  # MGCE
HMMWV68  29  # MGCE
HMMWV69  31  # MGCE
HMMWV70  33  # MGCE
HMMWV71  33  # MGCE
HMMWV72  33  # MGCE 50
HMMWV73  34  # MGCE
HMMWV74  37  # MGCE
HMMWV75  37  # MGCE {ON PURPOSE}
HMMWV76  38  # MGCE
HMMWV77  38  # MGCE
HMMWV78  39  # MGCE
HMMWV79  40  # MGCE
HMMWV80  42  # MGCE
HMMWV81  50  # MGCE
HMMWV82  52  # MGCE 60
HMMWV83  53  # MGCE
HMMWV84  55  # MGCE
HMMWV85  64  # MGCE
HMMWV86  66  # MGCE
HMMWV87  67  # MGCE
HMMWV88  68  # MGCE
HMMWV89  69  # MGCE
HMMWV90  70  # MGCE
HMMWV91  71  # MGCE
HMMWV92  72  # MGCE 70
HMMWV93  73  # MGCE
HMMWV94  82  # MGCE
HMMWV95  85  # MGCE
HMMWV96  89  # MGCE
HMMWV97  90  # MGCE
HMMWV98  91  # MGCE
HMMWV99  92  # MGCE
HMMWV100 92  # MGCE
HMMWV101 93  # MGCE
HMMWV102 95  # MGCE 80
HMMWV103 95  # MGCE
HMMWV104 98  # MGCE
HMMWV105 100 # MGCE
HMMWV106 102 # MGCE
HMMWV107 105 # MGCE
HMMWV108 106 # MGCE
HMMWV109 108 # MGCE
HMMWV110 109 # MGCE
HMMWV111 110 # MGCE
HMMWV112 111 # MGCE 90
HMMWV113 112 # MGCE
HMMWV114 113 # MGCE
HMMWV115 114 # MGCE
HMMWV116 115 # MGCE
HMMWV117 116 # MGCE
HMMWV118 117 # MGCE
HMMWV119 118 # MGCE
HMMWV120 121 # MGCE
HMMWV121 129 # MGCE
HMMWV122 131 # MGCE 100
HMMWV123 132 # MGCE
HMMWV124 136 # MGCE
HMMWV125 144 # MGCE 103
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$$ 5th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
 HMMWVLONG  # 2nd kind of cargo in cargo list
 9          # Number of 2nd kind
# NAME    PRIORITY
HMMWVLONG8   4  # # MGCE
HMMWVLONG9   6  # # MGCE
HMMWVLONG10  8  # # MGCE
HMMWVLONG11  10 #  # MGCE
HMMWVLONG12  16 #  # MGCE
HMMWVLONG13  35 #  # MGCE
HMMWVLONG14  56 #  # MGCE
HMMWVLONG15  61 # # MGCE
HMMWVLONG16  75 # # MGCE
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$$ 6th Cargo Stuff $$$$
```

```
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
LVSLONG  # 2nd kind of cargo in cargo list
16          # Number of 2nd kind
# NAME    PRIORITY
LVSLONG7   2  # MEU
LVSLONG8   3  # MEU
LVSLONG9   6  # MEU
LVSLONG10  15  # MEU
LVSLONG11  17  # MEU
LVSLONG12  19  # MEU
LVSLONG13  20  # MEU
LVSLONG14  21  # MEU
LVSLONG15  22  # MEU
LVSLONG16  34  # MEU
LVSLONG17  39  # MEU
LVSLONG18  44  # MEU
LVSLONG19  45  # MEU
LVSLONG20  46  # MEU
LVSLONG21  47  # MEU
LVSLONG22  79  # MEU
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$$ 7th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
#$$$$ 8th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FIVETON        # 2nd kind of cargo in cargo list
19          # Number of 2nd kind
# NAME    PRIORITY
FIVETON8   73  # MEU
FIVETON9   91  # MEU
FIVETON32  13  # MGCE
FIVETON33  20  # MGCE
FIVETON34  23  # MGCE
FIVETON35  29  # MGCE
FIVETON36  49  # MGCE
FIVETON37  51  # MGCE
FIVETON38  52  # MGCE
FIVETON39  52  # MGCE {ON PURPOSE}
FIVETON40  54  # MGCE
FIVETON41  55  # MGCE
FIVETON42  58  # MGCE
FIVETON43  60  # MGCE
FIVETON44  61  # MGCE
FIVETON45  79  # MGCE
FIVETON46  81  # MGCE
FIVETON47  82  # MGCE
FIVETON48  94  # MGCE
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$$ 9th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FIVETONLONG  # 2nd kind of cargo in cargo list

1            # Number of 2nd kind
# NAME    PRIORITY
FIVETONLONG5  33   # MEU
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$ 10th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
COMPRESSOR  # 2nd kind of cargo in cargo list
 2           # Number of 2nd kind
# NAME    PRIORITY
COMPRESSOR1  8  # MEU
COMPRESSOR2  54 # MEU
   2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$ 11th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
TRACTOR  # 2nd kind of cargo in cargo list
11          # Number of 2nd kind
# NAME    PRIORITY
TRACTOR1   8 #  # MEU
TRACTOR2  13 #  # MEU
TRACTOR3  16 #  # MEU
TRACTOR4  18 #  # MEU
TRACTOR5  23 #  # MEU
TRACTOR6  28 #  # MEU
TRACTOR7  37 #  # MEU
TRACTOR8  38 #  # MEU
TRACTOR9  40 #  # MEU
TRACTOR10 43 #  # MEU
TRACTOR11 44 #  # MEU
  2          # Number of Junctions in JunctPath
LUMMUS       # 1st Junction in Junction Path
BEACH        # ...
# Nth Junction in Junction Path
#$$$ 12th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
GRADER  # 2nd kind of cargo in cargo list
 1          # Number of 2nd kind
# NAME    PRIORITY
GRADER1  9  # MEU
```

```
 2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
#$$$ 13th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORK_EXT  # 2nd kind of cargo in cargo list
7         # Number of 2nd kind
# NAME   PRIORITY
FORK_EXT1  11  # # MEU
FORK_EXT2  31  # # MEU
FORK_EXT3  34  # # MEU
FORK_EXT4  38  # # MEU
FORK_EXT5  44  # # MEU
FORK_EXT6  53  # # MEU
FORK_EXT7  70  # # MEU
 2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
#$$$ 14th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
FORK_RT  # 2nd kind of cargo in cargo list
4         # Number of 2nd kind
# NAME   PRIORITY
FORK_RT1  93  # MEU
FORK_RT2  101 # MEU
FORK_RT3  103 # MEU
FORK_RT4  35  # MGCE
 2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
 #$$$ 15th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
 LAV        # 2nd kind of cargo in cargo list
 9        # Number of 2nd kind
# NAME   PRIORITY
LAV1  49  # MEU
LAV2  50  # MEU
LAV3  30  # MGCE
LAV4  31  # MGCE
LAV5  32  # MGCE
LAV6  33  # MGCE
LAV7  45  # MGCE
LAV8  46  # MGCE
LAV9  47  # MGCE
 2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
#$$$ 16th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
WELDER      # 2nd kind of cargo in cargo list
 2        # Number of 2nd kind
# NAME   PRIORITY
WELDER1  32  # # MEU
WELDER2  54  # # MEU   2
# Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
 BEACH      # ...
# Nth Junction in Junction Path
#$$$ 17th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
HOWITZER     # 2nd kind of cargo in cargo list
 6        # Number of 2nd kind
# NAME   PRIORITY
HOWITZER1  43  # # MGCE
HOWITZER2  44  # # MGCE
HOWITZER3  45  # # MGCE
HOWITZER4  46  # # MGCE
HOWITZER5  47  # # MGCE
HOWITZER6  48  # # MGCE
 2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
#$$$ 18th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
WATER_DIST  # 2nd kind of cargo in cargo list
 1         # Number of 2nd kind
# NAME   PRIORITY
WATER_DIST1  54  # # MEU
  2        # Number of Junctions in JunctPath
LUMMUS     # 1st Junction in Junction Path
BEACH      # ...
# Nth Junction in Junction Path
#$$$ 19th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
 CONTAINER # 1st kind of cargo in cargo list
95       # Number of 1st kind
# NAME   PRIORITY
CONTWATER1 3  # # MCSSE
CONTWATER2 4  # # MCSSE
CONTWATER3 5  # # MCSSE
CONTWATER4 6  # # MCSSE
CONTWATER5 8  # # MCSSE
CONTWATER6 10 # # MCSSE
CONTMED1  8  # # MCSSE
CONTMED2  16  # # MCSSE
CONTMED3  20  # # MCSSE
CONTMED4  34  # # MCSSE
```

CONTMED5 38 # # MCSSE
CONTMED6 45 # # MCSSE
CONTMED7 37 # # MCSSE
CONTMED8 41 # # MCSSE
CONTMED9 27 # # MCSSE
CONTMED10 13 # # MCSSE
CONTMRE8 3 # # MCSSE
CONTMRE9 11 # # MCSSE
CONTMRE10 23 # # MCSSE
CONTMRE11 9 # # MCSSE
CONTMRE12 1 # # MCSSE
CONTMRE13 3 # # MCSSE
CONTMRE14 24 # # MCSSE
CONTMRE15 19 # MACE
CONTMRE16 19 # MACE
CONTMRE17 25 # MACE
CONTMRE18 15 # MACE
CONTMRE19 7 # MACE
CONTMRE20 1 # MACE
CONTMRE21 9 # MACE
CONTFUEL1 41 # # MCSSE
CONTFUEL2 2 # # MCSSE
CONTFUEL3 35 # # MCSSE
CONTFUEL4 44 # # MCSSE
CONTFUEL5 15 # # MCSSE
CONTFUEL6 30 # # MCSSE
CONTFUEL7 10 # # MCSSE
CONTFUEL8 4 # # MCSSE
CONTFUEL9 15 # # MCSSE
CONTFUEL10 6 # # MCSSE
CONTFUEL11 16 # # MCSSE
CONTFUEL12 46 # # MCSSE
CONTFUEL13 14 # # MCSSE
CONTFUEL14 43 # # MCSSE
CONTFUEL15 42 # # MCSSE
CONTFUEL16 16 # # MCSSE
CONTFUEL17 18 # # MCSSE
CONTFUEL18 51 # # MCSSE
CONTFUEL19 45 # # MCSSE
CONTFUEL20 43 # # MCSSE
CONTHERS1 41 # MACE
CONTHERS2 41 # MACE
CONTHERS3 27 # MACE
CONTHERS4 27 # MACE
CONTHERS5 41 # MACE
CONTGENL1 8 # # MCSSE
CONTGENL2 16 # # MCSSE
CONTGENL3 20 # # MCSSE
CONTGENL4 34 # # MCSSE
CONTGENL5 38 # # MCSSE
CONTGENL6 45 # # MCSSE
CONTGENL7 13 # # MCSSE
CONTGENL8 3 # # MCSSE
CONTGENL9 29 # # MCSSE
CONTGENL10 52 # # MCSSE
CONTGENL11 14 # # MCSSE
CONTGENL12 37 # # MCSSE
CONTGENL13 41 # # MCSSE
CONTGENL14 27 # # MCSSE
CONTGENL15 8 # # MCSSE
CONTGENL16 16 # # MCSSE
CONTGENL17 20 # # MCSSE
CONTGENL18 34 # # MCSSE
CONTGENL19 38 # # MCSSE
CONTGENL20 45 # # MCSSE
CONTGENL21 15 # MACE
CONTGENL22 11 # MACE
CONTGENL23 36 # MACE
CONTGENL24 32 # MACE
CONTGENL25 7 # MACE
CONTGENL26 9 # MACE
CONTGENL27 46 # MACE
CONTGENL28 28 # MACE
CONTGENL29 23 # MACE
CONTGENL30 12 # MACE
CONTGENL31 16 # MACE
CONTGENL32 25 # MACE
CONTGENL33 7 # MACE
CONTGENL34 15 # MACE
CONTGENL35 11 # MACE
CONTGENL36 36 # MACE
CONTGENL37 32 # MACE
CONTGENL38 7 # MACE
CONTGENL39 9 # MACE
CONTGENL40 46 # MACE
3 # Number of Junctions in JunctPath
LUMMUS # 1st Junction in Junction Path
BEACH
COT2 # Nth Junction in Junction Path
#$$$ 20th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
CONTAINER # 1st kind of cargo in cargo list
19 # Number of 1st kind
NAME PRIORITY
CONTNSE1 2 # NSE
CONTNSE2 27 # NSE
CONTNSE3 30 # NSE
CONTNSE4 23 # NSE
CONTNSE5 25 # NSE
CONTNSE6 9 # NSE
CONTNSE7 17 # NSE
CONTNSE8 19 # NSE

```
CONTNSE9  13  # NSE
CONTNSE10 32  # NSE
CONTNSE11 10  # NSE
CONTNSE12 28  # NSE
CONTNSE13 31  # NSE
CONTNSE14 21  # NSE
CONTNSE15  6  # NSE
CONTNSE16 20  # NSE
CONTNSE17 18  # NSE
CONTNSE18 22  # NSE
CONTNSE19 14  # NSE
 3          # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH
COTNSE      # Nth Junction in Junction Path
#$$$ 21st Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
 HMMWV      # 2nd kind of cargo in cargo list
33          # Number of 2nd kind
# NAME   PRIORITY
HMMWV31  35  # MCSS
HMMWV32  40  # MCSS
HMMWV33  49  # MCSS
HMMWV34  56  # MCSS
HMMWV35  59  # MCSS
HMMWV36  62  # MCSS
HMMWV27  62  # MCSS {SAME ON PURPOSE}
HMMWV28  69  # MCSS
HMMWV29  74  # MCSS
HMMWV30  76  # MCSS 10
HMMWV31  81  # MCSS
HMMWV32  83  # MCSS
HMMWV33  97  # MCSS
HMMWV33  99  # MCSS
HMMWV34  128 # MCSS
HMMWV1    4  # MACE
HMMWV2   32  # MACE
HMMWV3   41  # MACE
HMMWV4   43  # MACE
HMMWV5   45  # MACE 20
HMMWV6   47  # MACE
HMMWV7   50  # MACE
HMMWV8   77  # MACE
HMMWV9   78  # MACE
HMMWV10  81  # MACE
HMMWV11  93  # MACE
HMMWV12  94  # MACE
HMMWV13  96  # MACE
HMMWV14  96  # MACE
HMMWV15  105 # MACE 30
HMMWV16  107 # MACE
HMMWV17  119 # MACE
HMMWV18  120 # MACE 33
 2          # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 22nd Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
 HMMWVLONG  # 2nd kind of cargo in cargo list
 7          # Number of 2nd kind
# NAME   PRIORITY
HMMWVLONG1  36  # MACE
HMMWVLONG2  39  # MACE
HMMWVLONG3  41  # MACE
HMMWVLONG4  51  # MACE
HMMWVLONG5  79  # MACE
HMMWVLONG6  26  # MCSS
HMMWVLONG7  73  # MCSS
 2          # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 23rd Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$
LVSLONG     # 2nd kind of cargo in cargo list
 6          # Number of 2nd kind
# NAME   PRIORITY
LVSLONG1  80  # MACE
LVSLONG2  1   # MCSS
LVSLONG3  3   # MCSS
LVSLONG4  4   # MCSS
LVSLONG5  41  # MCSS
LVSLONG6  200 # MCSS
 2          # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 24th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$
FIVETON     # 2nd kind of cargo in cargo list
29          # Number of 2nd kind
# NAME   PRIORITY
FIVETON1   30  # MACE
FIVETON2   35  # MACE
FIVETON3   48  # MACE
FIVETON4   62  # MACE
FIVETON5   65  # MACE
FIVETON6   72  # MACE
FIVETON7   83  # MACE
FIVETON10  2   # MCSS
FIVETON11  32  # MCSS
```

```
FIVETON12  32 # MCSS {SAME ON PURPOSE}
FIVETON13  34  # MCSS
FIVETON14  36  # MCSS
FIVETON15  37  # MCSS
FIVETON16  40  # MCSS
FIVETON17  41  # MCSS
FIVETON18  42  # MCSS
FIVETON19  59  # MCSS
FIVETON20  66  # MCSS
FIVETON21  66 # MCSS {SAME ON PURPOSE}
FIVETON22  67  # MCSS
FIVETON23  68  # MCSS
FIVETON24  70  # MCSS
FIVETON25  71  # MCSS
FIVETON26  72  # MCSS
FIVETON27  76  # MCSS
FIVETON28  78  # MCSS {WRECKER}
FIVETON29  80  # MCSS
FIVETON30  87  # MCSS
FIVETON31  90  # MCSS
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 25th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
FIVETONLONG  # 2nd kind of cargo in cargo list
 4          # Number of 2nd kind
# NAME    PRIORITY
FIVETONLONG1    19    #  MACE
FIVETONLONG2    31    #  MACE
FIVETONLONG3    33    # MACE
FIVETONLONG4    54    # MACE
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 26th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
FIRETRUCK     # 2nd kind of cargo in cargo list
 1          # Number of 2nd kind
# NAME    PRIORITY
FIRETRUCK1  9  # MCSS
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 27th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
EMI_SHELTER  # 2nd kind of cargo in cargo list
1           # Number of 2nd kind
# NAME    PRIORITY
EMI_SHELTER1  100  #  MACE
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 28th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
REFUELER    # 2nd kind of cargo in cargo list
 1          # Number of 2nd kind
# NAME    PRIORITY
REFUELER1  48  # MACE
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#$$$ 29th Cargo Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$
SCRAPER     # 2nd kind of cargo in cargo list
 1          # Number of 2nd kind
# NAME    PRIORITY
SCRAPER1  7  # MCSS
  2         # Number of Junctions in JunctPath
LUMMUS      # 1st Junction in Junction Path
BEACH       # ...
# Nth Junction in Junction Path
#*****************************
# ***TRANSPORTER LIST STUFF***
#*****************************
#$$$$ 1st Transporter Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
LIGHTER(1+1)  # 1st kind of trans in trans list
1           # Number of 1st kind
# list with names / locations of trans at this junct
LIGHTER(1+1)1  # Name  {1st kind}
0 0         # Location.x   Location.y
            # ... nth Name {1st kind}
# ... Nth Location.x    Location.y
# number of Junct in LEGALDESTA and  names
 2          # Number in Legal Dest A List
LUMMUS      # 1st in A list
BEACH       # 2nd in A list
# number of Junct in LEGALDESTB and names
2           # Number in B list
LUMMUS      # 1st in B list
BEACH       # 2nd in B list
LUMMUS      # Orig Junct
#$$$$ 2nd Transporter Stuff $$$$
#$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
LIGHTER(1+2)  # 1st kind of trans in trans list
 2          # Number of 1st kind
```

```
# list with names / locations of trans at this junct
LIGHTER(1+2)1  # Name  {1st kind}
 0 0          # Location.x   Location.y
LIGHTER(1+2)2  # Name  {1st kind}
 0 0          # Location.x   Location.y
          # ... nth Name {1st kind}
 # ... Nth Location.x    Location.y
 # number of Junct in LEGALDESTA and names
  2          # Number in Legal Dest A List
LUMMUS       # 1st in A list
BEACH        # 2nd in A list
 # number of Junct in LEGALDESTB and names
2          # Number in B list
LUMMUS       # 1st in B list
BEACH        # 2nd in B list
 LUMMUS      # Orig Junct
# ***********************
# **LOADER LIST STUFF**
# ***********************
CRANE        # 1st kind of loader in load list
 3           # Number of 1st kind
\\

BEACH ->
0  # Number of Cargo "Types"
0  # Number of Trans "Types"
0  # Number of Load  "Types"
 \\

COT1 ->
 0  # Number of Cargo "Types"
 0  # Number of Trans "Types"
0  # Number of Load  "Types"
\\

COT2 ->
0  # Number of Cargo "Types"
0  # Number of Trans "Types"
0  # Number of Load  "Types"
 \\

COTNSE ->
 0  # Number of Cargo "Types"
0  # Number of Trans "Types"
0  # Number of Load  "Types"
 \\

LIGHTER(1+1)1 ->
 0  # Number of Cargo "Types"
 0  # Number of Trans "Types"
 0  # Number of Load  "Types"
\\

LIGHTER(1+2)1 ->
0  # Number of Cargo "Types"
0  # Number of Trans "Types"
0  # Number of Load  "Types"
\\

 LIGHTER(1+2)2 ->
0  # Number of Cargo "Types"
0  # Number of Trans "Types"
 0  # Number of Load  "Types"
\\
```

APPENDIX B - OUTPUT DATA FILES

1 COT WITH 2 RTCH'S AT THE BEACH - 100% R

REP #	MEAN	VAR	SAMPLE	CI
1.000000	5329.362496	0.000000	5329.362496	0.000000
2.000000	5458.239135	33218.376613	5587.115775	505.196428
3.000000	5235.002887	166112.455523	4788.530392	922.415387
4.000000	5171.324163	126961.556720	4980.287990	698.380639
5.000000	5196.643234	98426.444399	5297.919520	549.992748
6.000000	5133.205623	102887.139167	4816.017563	513.323312
7.000000	5086.650396	100911.006430	4807.319037	470.658944
8.000000	5110.469244	91033.848658	5277.201183	418.160037
9.000000	5120.587685	80576.063189	5201.535212	370.909396
10.000000	5126.802151	72009.363182	5182.732347	332.644657
11.000000	5102.891692	71097.237615	4863.787098	315.149112
12.000000	5129.628400	73212.070686	5423.732182	306.187029
13.000000	5129.067643	67115.152620	5122.338563	281.659680
14.000000	5137.412818	62927.435765	5245.900090	262.810109
15.000000	5129.424482	59389.821539	5017.587782	246.658705
16.000000	5135.125931	55950.604448	5220.647667	231.808025
17.000000	5120.344006	56168.281671	4883.833213	225.323856
18.000000	5107.337590	55909.268878	4886.228505	218.469956
19.000000	5133.586680	65894.478917	5606.070314	230.852074
20.000000	5112.307134	71482.730057	4707.995759	234.353603
21.000000	5099.105583	71568.493507	4835.074562	228.842855
22.000000	5118.860004	76745.686786	5533.702833	231.527038
23.000000	5124.695971	74040.592191	5253.087242	222.411424
24.000000	5125.912561	70856.958235	5153.894146	212.996123
25.000000	5115.717307	70503.165345	4871.031198	208.171068
26.000000	5127.235375	71132.351787	5415.187071	205.037348
27.000000	5129.154945	68495.980367	5179.063775	197.440721
28.000000	5139.532444	68974.482007	5419.724927	194.558977
29.000000	5124.960449	72669.055844	4716.944586	196.228384
30.000000	5125.324621	70167.204974	5135.885615	189.580004

1 COT WITH 2 RTCH'S AT THE BEACH - 93 % R

REP #	MEAN	VAR	SAMPLE	CI
1.000000	5308.937786	0.000000	5308.937786	0.000000
2.000000	5132.692073	62125.102567	4956.446360	690.883194
3.000000	5151.126495	32082.035017	5187.995339	405.374470
4.000000	5166.197599	22296.575993	5211.410909	292.667946
5.000000	5149.017230	18198.257284	5080.295757	236.491734
6.000000	5164.110312	15925.412615	5239.575724	201.955548
7.000000	5109.298511	34301.512302	4780.427702	274.406049
8.000000	5098.402003	30351.167301	5022.126449	241.450869
9.000000	5083.874933	28456.593306	4967.658371	220.422674
10.000000	5100.051496	27911.561407	5245.640560	207.099063
11.000000	5091.552351	25914.995404	5006.560900	190.267798
12.000000	5101.869426	24836.391241	5215.357254	178.336275
13.000000	5073.567067	33179.997417	4733.938766	198.039839
14.000000	5079.805861	31172.605625	5160.910183	184.973111
15.000000	5146.065586	94801.257365	6073.701729	311.635903
16.000000	5151.032678	88875.925632	5225.539062	292.158243
17.000000	5146.834197	83620.843364	5079.658506	274.927940
18.000000	5128.558388	84714.064059	4817.869626	268.922768
19.000000	5138.392858	81845.346220	5315.413310	257.280139
20.000000	5155.778688	83583.038692	5486.109474	253.413733
21.000000	5140.893371	84056.912931	4843.187022	248.006542
22.000000	5199.021912	154390.603158	6419.721275	328.386397
23.000000	5218.436853	156042.467053	5645.565558	322.881791
24.000000	5203.996836	154262.350283	4871.876440	314.275422
25.000000	5190.956368	152086.097282	4877.985144	305.746026
26.000000	5175.448178	152255.756910	4787.743408	299.975824
27.000000	5176.532918	146431.536137	5204.736173	288.683189
28.000000	5184.023014	142578.988840	5386.255597	279.727276
29.000000	5164.001257	149112.133628	4603.392069	281.088812
30.000000	5155.373242	146203.615353	4905.160798	273.655698

1 COT WITH 2 RTCH'S AT THE COT - 100 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5426.406027	0.0000000000	5426.406027	0.000000
2.0000000	5355.025255	10190.429163	5283.644483	279.812625
3.0000000	5317.794934	9253.5051370	5243.334290	217.710099
4.0000000	5243.328684	28349.892888	5019.929934	330.013558
5.0000000	5206.424221	28072.116504	5058.806370	293.723466
6.0000000	5142.511688	46966.564693	4822.949021	346.820564
7.0000000	5183.577569	50943.649942	5429.972854	334.412171
8.0000000	5157.082605	49281.850557	4971.617857	307.669593
9.0000000	5102.901128	69542.310745	4669.449317	344.579448
10.000000	5062.388105	78228.437837	4697.770896	346.711619
11.000000	5021.033052	89218.238169	4607.482527	353.034010
12.000000	5045.796075	88465.976501	5318.189320	336.576339
13.000000	5039.962243	81536.248565	4969.956256	310.448634
14.000000	5052.937370	77621.184338	5221.614021	291.885272
15.000000	5072.990819	78108.926798	5353.739117	282.872529
16.000000	5138.653230	141886.499342	6123.589387	369.144679
17.000000	5136.302523	133112.532110	5098.691215	346.873465
18.000000	5125.923693	127221.345314	4949.483577	329.556443
19.000000	5139.803787	123813.976063	5389.645482	316.441986
20.000000	5140.594566	117309.957623	5155.619359	300.219231
21.000000	5134.036764	112347.559801	5002.880727	286.720167
22.000000	5122.865662	109743.133288	4888.272526	276.862034
23.000000	5105.759247	111485.285774	4729.418125	272.917211
24.000000	5098.875904	107775.229513	4940.559000	262.687813
25.000000	5088.357249	106050.647140	4835.909547	255.312880
26.000000	5071.033854	109611.221828	4637.948974	254.522923
27.000000	5074.951775	105809.858303	5176.817704	245.395871
28.000000	5088.586692	107096.481733	5456.729456	242.434629
29.000000	5085.008529	103642.901611	4984.819970	234.345625
30.000000	5117.361276	131470.014913	6055.590928	259.500857

1 COT WITH 2 RTCH'S AT THE COT - 93 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5476.088090	0.00000000000	5476.088090	0.000000
2.0000000	5738.406481	137621.877193	6000.724873	1028.288095
3.0000000	5547.562480	178075.237248	5165.874477	955.052411
4.0000000	5433.871450	170419.425569	5092.798362	809.125000
5.0000000	5386.584441	138994.875346	5197.436405	653.582566
6.0000000	5252.968436	218315.322220	4584.888407	747.743335
7.0000000	5215.523122	191744.495706	4990.851241	648.781563
8.0000000	5232.272329	166596.712372	5349.516778	565.684510
9.0000000	5240.127963	146327.522126	5302.973031	499.836333
10.000000	5194.691723	150713.426828	4785.765571	481.240356
11.000000	5216.377521	140815.096232	5433.235499	443.521148
12.000000	5190.999441	135742.286985	4911.840565	416.920284
13.000000	5163.805112	134044.339991	4837.473158	398.050919
14.000000	5137.745621	133240.595704	4798.972242	382.419767
15.000000	5129.933119	124638.938232	5020.558083	357.328213
16.000000	5130.135230	116330.329268	5133.166901	334.250876
17.000000	5132.562067	109159.805843	5171.391462	314.118116
18.000000	5142.601160	104552.741764	5313.265740	298.756613
19.000000	5162.209595	106049.579845	5515.161425	292.862485
20.000000	5141.255294	109249.677726	4743.123573	289.721784
21.000000	5160.766954	111781.996052	5551.000149	285.997574
22.000000	5156.638231	106834.063635	5069.935048	273.167860
23.000000	5147.511494	103893.808365	4946.723281	263.461392
24.000000	5135.182677	103024.679926	4851.619879	256.833153
25.000000	5159.574994	113606.613770	5744.990614	264.251749
26.000000	5158.686425	109082.877638	5136.472205	253.908761
27.000000	5152.823733	105815.403684	5000.393734	245.402302
28.000000	5149.912021	102133.700561	5071.295791	236.750871
29.000000	5169.324762	109414.849166	5712.881507	240.782656
30.000000	5159.785067	108372.096568	4883.133921	235.604823

2 COT'S (CE & GCE AT COT1; ACE & CSSE AT COT2) - 100 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5231.935490	0.00000000000	5231.935490	0.000000
2.0000000	5090.742461	39870.9426290	4949.549432	553.476672
3.0000000	5341.915028	209198.446505	5844.260162	1035.153291
4.0000000	5381.881880	145855.028129	5501.782437	748.543036
5.0000000	5281.085967	160190.351438	4877.902316	701.647920
6.0000000	5132.038862	261442.518929	4386.803335	818.273622
7.0000000	5047.940476	267376.535289	4543.350161	766.123339
8.0000000	5057.833115	229962.801871	5127.081590	664.614587
9.0000000	5128.419716	246059.665158	5693.112520	648.164180
10.000000	5136.964117	219449.770276	5213.863727	580.702415
11.000000	5142.235429	197810.447250	5194.948546	525.671385
12.000000	5186.285064	203112.123295	5670.831047	509.992004
13.000000	5177.226492	187252.863389	5068.523632	470.466413
14.000000	5167.010104	174310.041128	5034.197061	437.404505
15.000000	5168.429150	161889.529279	5188.295794	407.239427
16.000000	5162.384017	151681.592186	5071.707017	381.673946
17.000000	5177.547405	146110.274496	5420.161616	363.414277
18.000000	5161.607920	142088.761911	4890.636670	348.280917
19.000000	5179.917405	140564.449964	5509.488150	337.168517
20.000000	5182.129601	133264.197196	5224.161315	319.983668
21.000000	5188.632054	127488.907139	5318.681114	305.430652
22.000000	5176.279759	124774.748921	4916.881568	295.214768
23.000000	5167.136219	121026.069052	4965.978329	284.355487
24.000000	5168.376202	115800.967473	5196.895825	272.293040
25.000000	5157.067467	114173.114279	4885.657830	264.909777
26.000000	5154.247958	109812.880199	5083.760218	254.756946
27.000000	5153.267799	105615.247100	5127.783664	245.170095
28.000000	5152.652063	101714.186922	5136.027209	236.264144
29.000000	5147.673543	98800.3217010	5008.274970	228.805388
30.000000	5154.112086	96637.0589700	5340.829820	222.483236

2 COT'S (CE & GCE AT COT1; ACE & CSSE AT COT2) - 93 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5579.028687	0.00000000000	5579.028687	0.000000
2.0000000	5270.136099	190829.262237	4961.243510	1210.858946
3.0000000	5167.536435	126994.703961	4962.337108	806.525763
4.0000000	5097.814001	104108.007431	4888.646697	632.409141
5.0000000	5006.900751	119407.100377	4643.247753	605.781688
6.0000000	4992.371744	96792.2325990	4919.726708	497.886895
7.0000000	5050.290743	104142.467163	5397.804739	478.135487
8.0000000	5003.818846	106542.069609	4678.515566	452.378168
9.0000000	5063.401547	125175.195152	5540.063154	462.300061
10.000000	5038.716051	117360.577502	4816.546582	424.665701
11.000000	5067.844698	114957.778588	5359.131168	400.736505
12.000000	5059.478973	105346.895642	4967.456001	367.287641
13.000000	5085.559720	105410.657282	5398.528681	352.985326
14.000000	5099.776058	100131.604909	5284.588452	331.518400
15.000000	5122.514052	100734.593110	5440.845970	321.240102
16.000000	5125.658798	94177.1844570	5172.829996	300.745354
17.000000	5105.553755	95162.7274190	4783.873063	293.288508
18.000000	5124.449463	95991.7799880	5445.676499	286.264067
19.000000	5138.092468	94195.4033210	5383.666554	276.009558
20.000000	5185.518335	134222.007886	6086.609809	321.131520
21.000000	5211.038743	141188.023070	5721.446900	321.421814
22.000000	5242.994263	156930.199460	5914.060181	331.076221
23.000000	5243.657574	149807.128165	5258.250427	316.364969
24.000000	5278.819943	172967.187159	6087.554427	332.783900
25.000000	5286.144682	167101.516033	5461.938416	320.483930
26.000000	5277.463835	162376.739993	5060.442667	309.785654
27.000000	5272.038253	156926.278228	5130.973113	298.849148
28.000000	5249.519965	165312.245736	4641.526197	301.203188
29.000000	5242.251616	160940.275250	5038.737826	292.024600
30.000000	5224.230372	165133.567465	4701.614301	290.832624

2 COT'S (CE, GCE, & CSSE AT COT1; ACE AT COT2) - 100 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5772.735190	0.00000000000	5772.735190	0.000000
2.0000000	5427.742407	238040.040961	5082.749624	1352.371710
3.0000000	5280.547015	184019.470877	4986.156231	970.861610
4.0000000	5279.036155	122688.778045	5274.503574	686.528375
5.0000000	5271.155864	92327.0784060	5239.634703	532.679044
6.0000000	5279.650479	74294.6135540	5322.123550	436.203460
7.0000000	5251.707507	67377.8455290	5084.049679	384.587892
8.0000000	5243.175010	58334.8670280	5183.447533	334.738125
9.0000000	5203.952699	64888.5160340	4890.174208	332.850132
10.000000	5166.177289	71948.4967350	4826.198602	332.504042
11.000000	5211.817889	87667.3551440	5668.223890	349.952159
12.000000	5191.778900	84516.3286450	4971.350019	328.977166
13.000000	5165.045798	86763.8650020	4844.248572	320.246090
14.000000	5173.093396	80996.4151320	5277.712165	298.163823
15.000000	5131.858048	100716.264846	4554.563187	321.210877
16.000000	5136.227892	94307.3757020	5201.775544	300.953159
17.000000	5123.965956	90969.2011290	4927.774974	286.753546
18.000000	5088.602533	108128.361984	4487.424342	303.822286
19.000000	5147.514171	168062.272649	6207.923664	368.675589
20.000000	5151.715767	159569.958050	5231.546090	350.143956
21.000000	5142.184814	153499.080686	4951.565745	335.142349
22.000000	5134.865385	147368.229540	4981.157377	320.831247
23.000000	5153.798658	148914.457322	5570.330681	315.420983
24.000000	5169.931741	148686.547870	5540.992631	308.543417
25.000000	5165.028279	143092.373334	5047.345211	296.568012
26.000000	5150.254705	143043.399514	4780.915342	290.759092
27.000000	5128.509605	150308.663790	4563.136996	292.480012
28.000000	5147.488472	154827.204061	5659.917902	291.494716
29.000000	5149.680117	149436.956907	5211.046160	281.394805
30.000000	5151.044729	144339.823425	5190.618497	271.905833

2 COT'S (CE, GCE, & CSSE AT COT1; ACE AT COT2) - 93 % R

REP #	MEAN	VAR	SAMPLE	CI
1.0000000	5600.629744	0.00000000000	5600.629744	0.000000
2.0000000	5416.817727	67573.7157010	5233.005709	720.543109
3.0000000	5290.703665	81501.1274480	5038.475542	646.111168
4.0000000	5385.696968	90428.9952500	5670.676876	589.399718
5.0000000	5363.926520	70191.5083307	5276.844731	464.454690
6.0000000	5310.984526	72970.3350460	5046.274556	432.298384
7.0000000	5260.021144	78989.4766580	4954.240852	416.410494
8.0000000	5236.649260	72075.2256580	5073.046067	372.078074
9.0000000	5240.998103	63236.0344210	5275.788853	328.584540
10.000000	5187.627470	84694.0532780	4707.291771	360.755139
11.000000	5208.969710	81235.0510140	5422.392105	336.869315
12.000000	5164.781440	97281.2840870	4678.710478	352.947485
13.000000	5200.398089	105665.604312	5627.797877	353.411935
14.000000	5164.399733	115679.823989	4696.421103	356.328745
15.000000	5173.503476	108660.151503	5300.955880	333.638063
16.000000	5166.273080	102252.599476	5057.817137	313.374212
17.000000	5162.460952	96108.861400	5101.466910	294.742880
18.000000	5155.267840	91386.734442	5032.984937	279.313157
19.000000	5147.325917	87508.102539	5004.371289	266.031706
20.000000	5156.936771	84749.783380	5339.543005	255.176319
21.000000	5166.545437	82451.149936	5358.718758	245.626250
22.000000	5145.979577	87829.905744	4714.096520	247.682849
23.000000	5130.355053	89452.529518	4786.615526	244.465997
24.000000	5116.785759	89982.306826	4804.691998	240.026398
25.000000	5107.131253	88563.281576	4875.423090	233.315135
26.000000	5105.981294	85055.132839	5077.232328	224.207252
27.000000	5117.598732	85427.832687	5419.652109	220.497606
28.000000	5112.478931	82997.784956	4974.244311	213.422549
29.000000	5095.929686	87976.025539	4632.550844	215.908250
30.000000	5109.697355	90628.830191	5508.959735	215.456017

APPENDIX C - PAIRWISE DIFFERENCES

option 1	option 2	option 3	option 4
20.42	-49.68	-347.09	172.11
630.67	-717.08	-11.69	-150.25
-399.46	77.46	881.92	-52.31
-231.12	-72.87	613.13	-396.18
217.62	-138.62	234.65	-36.91
-423.56	238.06	-532.93	275.85
26.89	439.12	-854.45	129.81
255.08	-377.9	448.56	110.4
233.88	-633.52	153.05	-385.62
-62.91	-88	397.31	118.91
-142.77	-825.75	-164.18	245.83
208.38	406.35	703.37	292.64
388.4	132.49	-330.01	-783.55
84.99	422.64	-250.39	581.29
-1,056.11	333.18	-252.55	-746.4
-4.89	990.42	-101.12	143.95
-195.82	-72.7	636.29	-173.7
68.35	-363.78	-555.03	-545.56

	290.66	-125.52	125.82	1,203.55
	-778.12	412.5	-862.45	-107.99
	-8.11	-548.12	-402.78	-407.15
	-886.02	-181.66	-997.18	267.07
	-392.47	-217.3	-292.27	783.71
	282.02	88.94	-890.65	736.3
	-6.96	-909.08	-576.28	171.93
	627.45	-498.52	23.32	-296.32
	-25.67	176.43	-3.19	-856.51
	33.46	385.44	494.5	685.68
	113.55	-728.06	-30.47	578.49
	230.73	1,172.46	639.22	-318.34
Mean Difference	-30.048	-42.4223	-70.119	41.3577
Standard Deviation	475.223		**T**	**-0.5834**

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